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A HISTORY AND BIBLIOGRAPHY OF THE STUDY OF FOSSIL VERTEBRATE FOOTPRINTS IN THE BRITISH ISLES

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ABSTRACT

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A comprehensive account is given of the discovery and study of the fossil footprints of vertebrates in the British Isles. Brief summaries are given of work published in journals that are generally available to the geologist at large; however, since many papers were published in obscure books and journals, the illustrations in these are reproduced and the papers themselves directly quoted wherever appropriate. A number of specimens important in the history of British vertebrate ichnology are illustrated for the first time; in particular, the holotype of *Chelichnus ingens* Binney (1856), the "Kegworth footprint" from Leicestershire, the supposed "monotreme footprint" of Seeley (1899), and the first *Iguanodon* footprint to be described from Sussex (Tagart, 1846). Illustrations are given for the first time of footprints from the Forest Marble of Wiltshire thought to be those collected by Scrope (1831), of a footprint from the Permian of Warwickshire, mentioned by Vernon (1912), and of a footprint from Caithness. The account is extensively supplemented by text-figures of principal footprint types and, so far as possible, the present whereabouts of figured or described specimens is indicated. (Many, unfortunately, are lost.) An exhaustive bibliography of fossil vertebrate footprints from the British Isles is presented.

Particular attention is paid to the important discoveries in the Cheshire Basin by the amateur geologists of the Liverpool region. An account of the work of Henry C. Beasley (1836—1919), the most eminent British worker in this field, is given for the first time; his portrait, and photographs relating to his work in the Storeton quarries, are published for the first time.

The stratigraphical and palaeoecological significance of the footprints is assessed wherever possible and reasons are presented why a more extensive resumption of work in this field is desirable.

INTRODUCTION

> "But after all, Thorndyke, this is a matter of reasoning, as I said, of thinking about the footprints and their meaning. No special acuteness of observation or training of vision comes into it. The mere facts are obvious enough: it is their interpretation that yields the knowledge."
>
> R. Austin Freeman (The Seal of Nebuchadnezzar)

Even when one is deliberately searching for fossil vertebrate footprints, they are not easy objects to find. The footprints themselves (the moulds) form indentations in the surfaces of strata and are only readily revealed by shadowing under oblique lighting; when light comes from overhead, they are scarcely visible at all. The casts (the sedimentary infilling of the footprints) since they are situated on the undersurfaces of beds, are only likely to be seen after rock collapse or in the course of quarrying. It is perhaps not surprising, therefore, that no fossil vertebrate footprints are illustrated in the early works of alchemists and naturalists and that their discovery was a relatively late event in the history of palaeontology.

The first recorded human observation of fossil vertebrate footprints was in 1802 in the valley of the Connecticut River, near South Hadley, Massachusetts, U.S.A. A boy called Pliny Moody discovered them — birdlike tracks impressed into red sandstones later to be recognised as of Triassic age [304, pp.41—42] *. The discovery attracted much local publicity, but no scientist examined them at the time; indeed, it was not until 1836 that Professor Edward Hitchcock of Amherst College published the first account of these tracks, naming them "ornithichnites" (since he was convinced that they were indeed bird tracks) and proposing a new science of "ornithichnology"! [308]. The idea was reasonable enough, but, when it eventually came to be shown that these were tracks of bipedal reptiles with a strikingly birdlike foot structure, Hitchcock's new science withered away. . .

Long before the first scientific studies of the Connecticut Valley tracks were made, however, the scientific world at large had been astonished by the description of fossil tracks from Scotland and then from England. British observations were to bulk large in footprint literature for almost a century, and some of the earliest attempts at using footprints for stratigraphical correlation were made by British geologists. Strangely, however, there have been no serious British attempts to formulate schemes for the classification of tracks. Such work has been entirely done elsewhere, by American geologists — most notably, Edward Hitchcock and Richard S. Lull — and by Austrian or German geologists — Wilhelm Pabst, Ferenc Nopcsa and, most recently, Oskar Kuhn and Hartmut Haubold (see review in Haubold [306]). Indeed, it has been primarily in Germany and the United States that fossil footprints have been studied in recent years.

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* Numbers between square brackets refer to the Bibliography (p.362), which is arranged by counties and countries of the British Isles.

In contrast, for the past 60 years, vertebrate footprints have been very much neglected by British stratigraphers and palaeontologists. Although occasional discoveries were reported from time to time, virtually no important studies were published between 1914 and 1963; and, even since that date, studies made have been few, the result of incidental research by a handful of people (in particular Mr. Justin B. Delair and the present writer) primarily concerned with other fields of endeavour. This neglect has developed despite the demonstration by foreign geologists that footprints are not only informative concerning the habits of long-extinct animals but are also useful indices of environments; indeed, they can afford a means of stratigraphical correlation and interpretation in continental sediments otherwise virtually barren of macrofossils. It is hoped that this review, by bringing together a great deal of information much of which was hitherto extremely difficult of access, may help to stimulate a renewal of this study in the British Isles.

If footprint finds and reports were to be dealt with in strict chronological order, the result would be geographical and geological confusion. I have therefore adopted the plan of organising the text primarily by country — Scotland, England, Ireland and Wales, in order of priority of discovery. The Scottish finds are thereafter dealt with by county, in order of priority of discovery. The system for England has been modified in view of the much greater number of records; this is organised by geologic system, thereafter by county. (Irish and Welsh finds are too few for similar subdivisions to be necessary.) The dates and, generally, the authors of references are indicated in the text, and the references are consistently cited by number.

Note: Since this is primarily a historical account and contains many direct quotations from early works, dimensions are consistently quoted in traditional English units of measurement (yards, feet and inches). To enable ready conversion to be made, however, some metric equivalences are given here: 1/4 in. = 6.35 mm; 1/2 in. = 1.27 cm; 1 in. = 2.54 cm; 4 in. = 10.16 cm; 8 in. = 20.32 cm; 1 ft. = 30.48 cm; 1 yard = 91.44 cm.

SCOTLAND

Dumfries-shire

About the year 1824, a slab of red sandstone, about 5 ft. 2 in. in length, was procured from a quarry at Corncockle Muir in Annandale; on it there were impressed a sequence of footprints, 24 in number, of the fore and hind feet of a quadrupedal animal. The individual footprints were not especially large, being little more than 2 in. (ca. 5 cm) in diameter. The impressions of fore and hind feet, though sufficiently distinct to be distinguished, were of essentially similar form, short-clawed and showing palm and sole impressions; the trackway was broad and the stride short. The slab was collected by Mr. Carruthers of Dormont and passed on by him to the Reverend Henry Duncan, Minister of Ruthwell; it was built into the wall of a summerhouse in the garden of Ruthwell Manse.

The discovery excited Duncan's interest so much that he visited the quarry himself and obtained a number of further footprint-bearing slabs. The Corncockle Muir quarry was situated in a tongue of land between the rivers Annan and Kinnel about 1½ miles above their confluence; the strata being worked for building stone were already recognised as equivalent to the "new red sandstones" of England. Corncockle Muir was destined to yield many fine vertebrate tracks and to become one of the two most famous British localities for vertebrate footprints.

Duncan felt himself not competent to decide on the nature of the animals which had made the tracks; he therefore sent casts of them to the Reverend William Buckland, Professor of Geology at the University of Oxford, for examination, before preparing an account of the footprints for public presentation. (At least one of these casts, specimen no. F.189/P, survives in the collection of the Oxford University Museum.) Buckland was convinced that the tracks must be those of reptiles, since he believed — correctly enough — that no higher types of animals were in existence at the time the "new red sandstones" were accumulating. Just after completing the writing of his account, Duncan received the following account of the experiments which Buckland had undertaken:

Oxford, 12th Dec. 1827.

"1st, I made a crocodile walk over soft pye-crust, and took impressions of his feet, which shew decidedly that your sandstone foot-marks are *not* crocodiles.

2nd, I made tortoises, of three distinct species, travel over pye-crust, and wet sand and soft clay; and the result is, I have little or no doubt that it is to animals of this genus that your impressions on the new red sandstone must be referred, though I cannot identify them with any of the living species on which I made my experiments. The form of the footsteps of a modern tortoise corresponds sufficiently well, but the relative position of the impressions to each other does not entirely correspond, and this I attribute to the different pace at which the animal was proceeding; for I found considerable variety in these positions as my tortoises moved more or less rapidly; and as most animals have three distinct kinds of impressions for their three paces of walk, trot, and gallop, so I conceive your wild tortoises of the red sandstone age would move with more activity and speed, and leave more distinct impressions from a more rapid and equable style of march, than my dull torpid prisoners on the present earth in this to them unnatural climate.

I found also, that, on walking down hill on soft sand, my tortoise scooped out long and somewhat oval cavities, like those of which you sent me a cast, leaving no impression of the toes or heel. Each foot successively floundered forwards to the lowest point of the groove producing a similar removal of sand from the anterior part of the groove in question. The difficulty is to explain why sand so soft did not subside and obliterate the cavities, before or during the arrival of the next superincumbent bed of sand, which filled up and preserved these impressions . . ." [15, pp.202—203]

Duncan had himself tried to solve this problem, but his solution is so hard to follow and so far from being convincing that it will not be expounded here. His account contains careful descriptions of three types of tracks, including the "sliding" tracks discussed by Buckland, and an illustration of the summerhouse slab.

Duncan's paper was read to the Royal Society of Edinburgh on January 7th, 1828, but was not destined to be published until 1831 [15]. A summary, by an anonymous reporter, was however published in the "London and Paris Observer" for February 10th, 1828 [3]; most unfortunately, the only known copy of this newspaper, which was lodged in the British Museum Library, was destroyed by a fire following war-time bombing and, unless some copy comes to light in the future, the contents of this earliest of all published accounts of fossil vertebrate footprints can never be ascertained. A second summary appeared, however, in the "London Journal of Arts and Science" during the same year [4], so that, although Duncan's paper may have been delayed, he was from the outset regarded as the true scientific discoverer of fossil vertebrate footprints.

Buckland's conclusions concerning the ability of tortoises to produce tracks comparable with those of Corncockle Muir seem to have encountered some initial scepticism. In consequence, he undertook some public experiments in footprint-making at a later date. A letter of John Murray III, son and successor of the distinguished publisher, vividly describes this occasion:

Jan. 23, 1828.

"I went on Saturday last to a party at Mr. Murchison's house, assembled to behold tortoises in the act of walking upon dough. Prof. Buckland acted as master of the ceremonies. There were present many other geologists and savants, among them Dr. Wollaston. At first the beasts took it into their heads to be refractory and to stand still. Hereupon the ingenuity of the professor was called forth in order to make them move. This he endeavoured to do by applying sundry flips with his fingers upon their tails; deil a bit however would they stir; and no wonder, for on endeavouring to take them up it was found that they had stuck so fast to the piecrust as only to be removed with half a pound of dough sticking to each foot. This being the case it was found necessary to employ a rolling pin, and to knead the paste afresh; nor did geological fingers disdain the culinary offices. It was really a glorious scene to behold all the philosophers, flour-besmeared, working away with tucked-up sleeves. Their exertions, I am happy to say, were at length crowned with success; a proper consistency of paste was attained, and the animals walked over the course in a very satisfactory manner; insomuch that many who came to scoff returned rather better disposed towards believing." [30, pp.7—8]

Buckland's interest in the casts sent by Duncan caused him to request that actual specimens be procured "at any expence" (sic) and sent to Oxford. In consequence, Duncan made a further expedition to the quarries to obtain the specimens which the Oxford professor required, taking along a friend, James Grierson. On November 22nd, 1828, Grierson gave a lucid description of the expedition to the Literary and Antiquarian Society of Perth; this was published in two journals, the "Edinburgh Journal of Sciences" and "Arcana" [17, 18]. (A briefer account of the lecture subsequently appeared in the "New Monthly Magazine" [19].) He noted that the footprints were displayed on a bedding-plane surface dipping at about 35° to the west, some 15 ft. of this surface being exposed over a distance of between 45 and 50 yards; no less than four separate tracks being visible:

"The great number of the impressions in uninterrupted continuity — the regular alternations of the right and left footstep — their equidistance from each other — the

outward direction of the toes — the grazing of the foot along the surface, before it was firmly planted — the deeper impression made by the toe than by the heel — the forcing forward of the sandy matter of the rock by the downward and scarcely slanting direction in which it is remarkable that all the animals have traversed this singular acclivity — — and in the largest specimen which Dr. Duncan has, and which was found in a different part of the quarry — the sharp, and well-defined marks of the three claws of the animal's foot — are circumstances which immediately arrest the attention of the observer. . ." [18, p.131]

Grierson's description of the footprints was so careful that it is surprising to find him assuming that the angle of the beds represented an original slope which the animals had ascended, without realising that, if this *had* been the case, the footprints would have had a form entirely dissimilar to that observed!

The slope presented problems to the collectors:

"The thinness of the slab, which rendered its separation so easy, rendered it at the same time so fragile, that it went to pieces in the hands of the person who was removing it to the bottom of the quarry, and who was forced into a running motion by the steepness of the path which he had to descend. Owing, however, to the comparative hardness of the parts which had been subjected to the pressure of the animal, the footmarks were but little injured by the fracture, and having collected and arranged on the spot as many of the fragments as we could clearly distinguish, they were afterwards put in a flat wooden case, and cemented with stucco, which, besides keeping them in their relative positions, served as a sort of compensation for those that were awanting." [18, p.132]

The number of specimens sent to Oxford is not clear; only two, a slab and counterpart (specimens F.187 and F.188), survive in the collections of the Oxford University Museum. It is probable that Buckland distributed any further specimens he received to other collections.

Buckland's continuing interest in the Dumfries-shire footprints, perhaps stimulated by the receipt of the slabs, was evidenced by his publishing a brief note on their probable mode of formation in a French journal [8]. On the basis of his experiments, he had correctly recognised that they were produced by reptiles with a broad trackway and short stride; as the fossil remains of the true trackmakers had not then been discovered, it was perfectly reasonable for him to fix on tortoises, since these were the only living reptiles capable of producing similar tracks. His work can be considered one of the earliest essays in direct experimentation with living animals as a basis for palaeoecological interpretation and deserves to be remembered with respect.

Interest in the Dumfries-shire footprints continued to mount during this period. James Grierson's account was published in translation in another French journal [20] and "K.N." published a synopsis of it in the second issue of the "Magazine of Natural History" [32]. In 1831, the interest of Gideon Mantell, famed as the discoverer of *Iguanodon*, was sufficiently stirred for him to discuss the tracks in a paper assessing the geological antiquity of reptiles [28, p.183]. In 1833, in the course of a spirited defence of the unerring geological accuracy of Holy Scripture, George Fairholme noted that he had been informed that Sir Everard Home, a prominent London surgeon

who dabbled in palaeontology, had concluded that the Corncockle Muir tracks were those of Chelonians [40, p.341]; whilst it is possible that Home had arrived at this idea independently, it is much more likely, in view of the freedom of scientific intercourse at that time, that Home was merely quoting Buckland's ideas.

In 1836, in his contribution to the series of "Bridgewater Treatises", Buckland not only mentioned Duncan's earlier work but also quoted from a letter from Duncan recording the discovery of footprints at a second locality, Craigs near Dumfries [9]. The Dumfries-shire footprints also gained passing mention in the "Proceedings" of the Geological Society of London for 1839 (Vol.3, p.31); and in 1841, the great anatomist Richard Owen gave the name *Testudo duncani* to the tracks from the summerhouse wall which Duncan had described [33] — thus (rather oddly) treating the tracks as if they were a living species of turtle!

When Duncan was appointed to the ministry of Mount Kedar Church, near Dumfries, he extracted the footprint slab from the wall of the Ruthwell Manse summerhouse and took it with him; it was eventually acquired by the Dumfries Burgh Museum in the mid-1950's. Others of his footprint slabs were exhibited during the nineteenth century in the Free School Museum, Edinburgh; they somehow survived the closure of this Museum and were eventually acquired by the Royal Scottish Museum in 1966 [11].

It was not until 1850 that any significant new contributions were made to knowledge of Dumfries-shire ichnology. In that year, Robert Harkness gave a general geological account of the New Red Sandstone of that county, mentioning footprints not only from Corncockle Muir and Craigs, but also from quarries at "Locherbriggs" near Dumfries, and at Green Mill, in the parish of Caerlaverock. He noted that the footprints were preserved at the interfaces between clay partings and sandstones. Even more interesting is his mention of "footsteps of the *Cheirotherium* in relief" from localities "about Annan", and apparently also (the phrasing is ambiguous) from the parish of Kirkpatrick Fleming. These occurrences are at a much younger level in the New Red Sandstone; Harkness' observation, at that time merely considered as an additional record from rocks of about the same stratigraphical level, represents the earliest record of vertebrate footprints in Dumfries-shire strata now considered to be of Triassic date [22]. In a second paper published in the same year, Harkness made it clear that the footprints from "about Annan" came primarily from the Corse Hill quarry [21]; he considered *all* the Dumfries-shire sandstones as being of Bunter (Lower Triassic) age.

In an appendix to Harkness' earlier paper, Sir William Jardine proposed new names for the tracks originally described by Duncan. Two new genera were erected: *Chelichnus*, represented by *C. duncani* (Owen) and *C. gigas*; and *Herpetichnus*, represented by *H. sauroplesius* and *H. bucklandi*. No illustrations were provided [25]. The former name reflects his adoption of Buckland's opinion that the tracks were made by chelonians; though subsequent work has contradicted this opinion, the inappropriate generic name he proposed retains its validity.

Harkness was clearly impressed by this new taxonomic procedure for dealing with fossil footprints since, in 1851, he described (rather too briefly) a series of other types of tracks under various new names: *Chelichnus plancus* (from Craigs, Locharbriggs and Green Mills), *C. obliquus*, *Chelaspodos jardini*, *Saurichnis acutus*, *Batrachichnis stricklandi* and *Labyrinthodon lyelli*, all from Green Mills. Once again, no illustrations were provided [23].

The Dumfries-shire footprints gained brief mention in the revised edition of Richardson's "Introduction to geology", published in 1851 [135, p.291], and in a paper read to the Ashmolean Society of Oxford in 1852 by Hugh Strickland [36].

The lack of illustrations of the Dumfries-shire prints was handsomely compensated for in 1853 by the publication by Sir William Jardine of a book that is probably the largest (about 2 ft. 6 in. x 1 ft. 6 in.), thinnest (only 17 pages), most lavishly illustrated (13 plates, all double-spread, all hand-coloured), rarest and most expensive in the entire field of ichnology — "The Ichnology of Annandale, or Illustrations of Footmarks impressed on the New Red Sandstone of Corncockle Muir" [26]. All the slabs were illustrated at actual size, subtly and excellently hand-coloured, and a fine panoramic view was provided of the Corncockle Muir quarries. Nine species were figured: the four

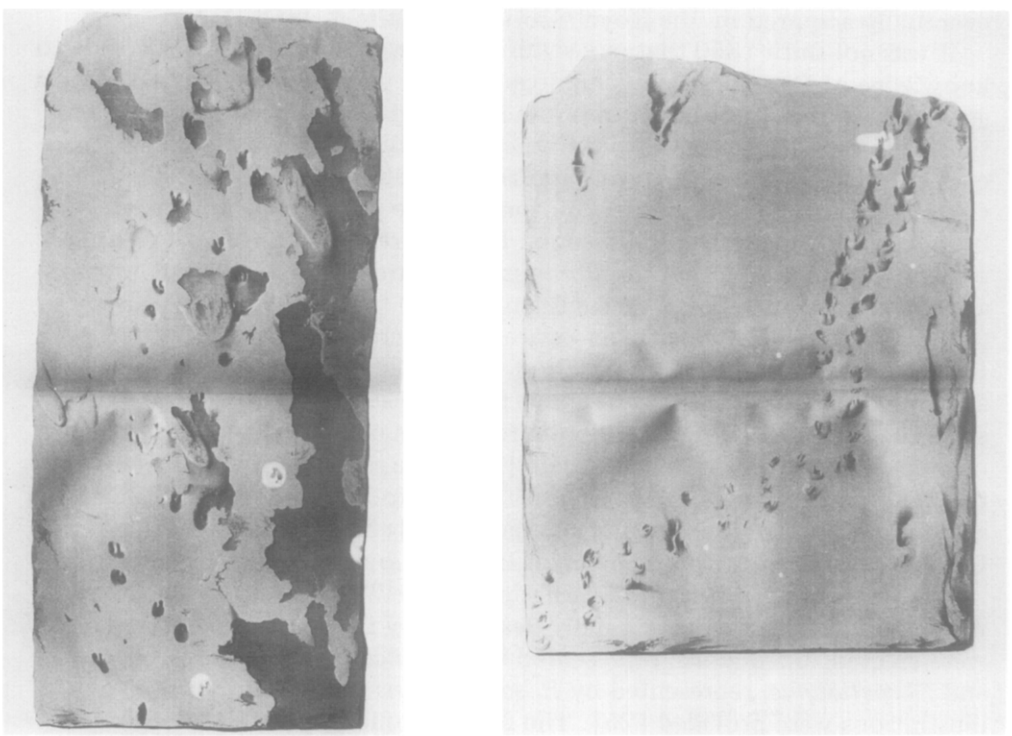

Fig.1. Two illustrations from Jardine's "Ichnology of Annandale" [26], here shown at greatly reduced size. Left: *Herpetichnus bucklandi* Jardine; right: *Chelichnus duncani* Owen.

named earlier by Jardine (see Fig.1); *Batrachichnis lyelli* (Harkness), appropriately removed from a genus based on fossil bones to one based on imprints; and four new species, *Chelichnus titan*, *C. ambiguus*, *C. plagiostopus* and *Actibates triassae*. In addition, "fossil raindrop impressions" (perhaps examples of the trace fossil *Planolites*?) were illustrated. The Triassic date proposed by Harkness was accepted, a new locality (Templand) reported, and the opinion that most of the tracks were made by reptiles expressed [26].

Jardine's fine private collection was housed in a special room, the "Footstep Room", at Jardine Hall, Applegarth. An ecstatic description of a visit to the Corncockle Muir quarry and to this room was given by the Rev. W. S. Symonds in 1857 [37, pp. 124–126]; he noted: "It is remarkable that all the tracks trend one way, and have never been observed returning. A wag remarked that they were *Scotch* reptiles travelling *South* and too good judges to think of coming back to their 'ain cauld countrie'." Symonds' drawing of the quarry, at that time nearing its closing stages of working, is here reproduced (Fig.2). However, Jardine's heirs proved less enthusiastic about palaeontology; as a result, the Jardine collection was acquired in 1875 by the Royal Scottish Museum, Edinburgh, where it is again available for examination, albeit in a less sumptuous setting!

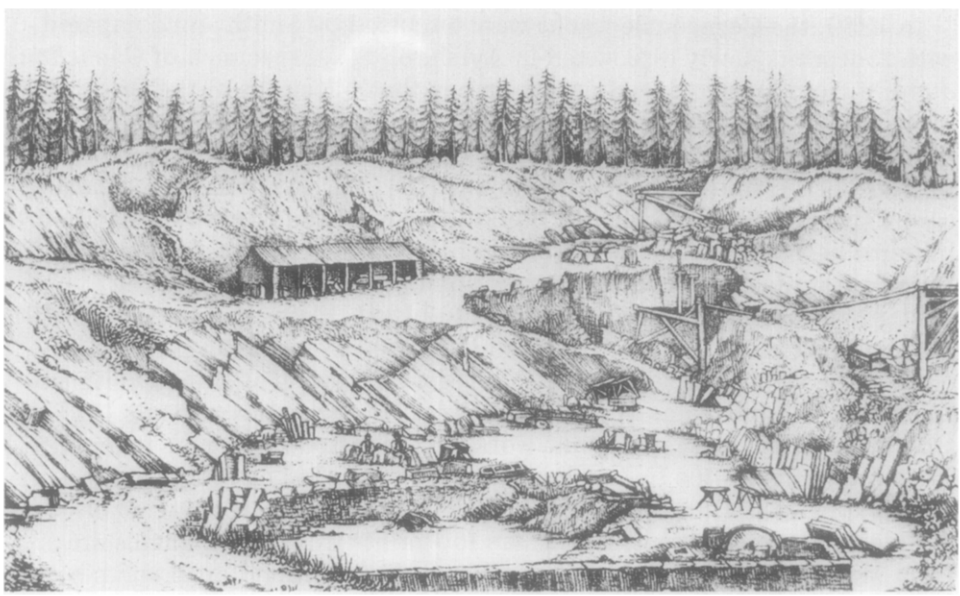

Fig.2. The Corncockle Muir quarries, Dumfries-shire, in 1856. (From W. S. Symonds' "Stones of the Valley" [37].)

The stratigraphic date of the Corncockle Muir imprints was questioned by E. W. Binney in 1856, who put forward instead the opinion that some of the New Red Sandstone deposits of South Scotland were Permian [6]. This view has since gained general acceptance. (Binney's erroneous citation of Green

Mills as "Greenbanks" should be noted.) Footprints from Corncockle Muir were mentioned in the seventh edition of Mantell's textbook "The Wonders of Geology" [250]. Two years later, they were illustrated in a German work by C. Vogt [38] and in 1862 in an anonymous book, "Pre-Adamite Man", published in London [5]. In 1859, Thomas Henry Huxley compared them with tracks from Morayshire [47], and in 1860, Richard Owen more surprisingly compared them with some totally dissimilar invertebrate tracks from Roxburghshire [58].

By 1878, P. Dudgeon, describing a new track from Dumfries-shire, was able to firmly label it "Permian". The track he described, a new type of *Herpetichnus* (*H. loxodactylus*), was from Locharbriggs [14]. The type specimen seems to have been acquired by Dr. Thomas B. Grierson and housed in his remarkable private museum at Thornhill: it appears to be the specimen numbered 272 in the catalogue of the museum [7, p.20: for discussion see 11, p.16]. This museum was finally broken up around 1965. The bulk of the geological material, including the footprint slabs, went to the Dumfries Burgh Museum, the remainder going to the Hunterian Museum, Glasgow, or the Royal Scottish Museum, Edinburgh. The published photographs of the specimens in their original setting [331, pl.1; 330, pl.24] unfortunately do not show the slabs.

In 1889, the Corncockle tracks were discussed by Smith and compared with footprints newly discovered in Ayrshire [1]. A specimen of *Chelichnus duncani* from Corncockle Muir was among the collections of the British Museum (Natural History) listed in 1890; its source is not known [27]. The tracks were discussed by Sir Archibald Geikie in 1901 and considered by him to have been formed by labyrinthodonts [16]; this idea had been advanced earlier by Harkness in his attribution of one set of the tracks, but had not hitherto been applied to the majority of the Corncockle tracks. The Dumfries-shire footprints gained incidental mention in several accounts of the stratigraphy of this region by Watt in 1902 [39], Horne and Gregory in 1916 [24], and Sherlock [34] and Cameron-Smith [10] in 1925.

In 1909, George Hickling published a general review of British Permian footprints. Despite some taxonomic failings (cf. Delair's comments [11]), this is one of the most important works in the history of British ichnology, since it constitutes the first serious attempt at employing footprints in stratigraphy. The Dumfries-shire footprints hitherto described were discussed in detail and similarities with Permian footprints from Nottinghamshire and from Morayshire were pointed out, whereas the profound differences between these footprints and those from the Triassic were stressed [209].

In 1936, Simpson and Richey recorded some three- and possibly four-toed imprints from Euchan Water, Nithsdale. These were undoubtedly Carboniferous, from the *Carbonicola ovalis* zone [35]. Unfortunately, their specimens have never been fully described and are apparently lost.

The Corncockle prints were discussed in Swinton's review of the history of *Chirotherium* [320] and specimens in Dumfries Museum, including some

collected during the 1880's by an amateur geologist, Mr. W. Price, were listed by McCracken in 1964 [29]. Both authors considered them to be of Permian age. A contrary view was later taken by Mykura, who considered them to be probably of Upper Carboniferous date [31]. The problem of their true age thus has still not been resolved.

Serious work on the Dumfries-shire footprints was resumed in 1966, after a gap of almost eighty years, when Justin B. Delair published an important paper briefly reviewing the history of their study, listing all specimens which he had been able to locate in museums, and describing four new species: *Chelichnus pricei*, *Cardiodactylum permicum*, *Prochirotherium truckelli* and *Herpetichnus robustus*. The first two species were based on specimens from Dumfries Museum collected by Price, the third also from Dumfries Museum but of unknown history, and the fourth on a specimen lodged in the Royal Scottish Museum, originally from Jardine's collection but never previously described [11].

In the following year, Delair listed and described Duncan's specimens from the Free Church Museum and others collected during the nineteenth century by one Dr. Duns [12]. Subsequently, in 1969, he published a note on a new find of Triassic quadrupedal footprints from the west bank of the River Annan, near Violet Bank; these were collected by two schoolboys and subsequently presented to the Dumfries Museum [13]. Since Harkness' specimens are lost and no other Triassic finds have been reported, this discovery was of particular interest: unfortunately the prints were not really of adequate quality for precise taxonomic allocation.

Despite the poor quality of the tracks from Violet Bank, they were given a new name, *Delairichnus annanensis*, by Hartmut Haubold (1971), in the course of his massive review of amphibian and reptilian footprints; no opinion was expressed concerning the systematic identity of the trackmaker [306, p.94]. All the principal Dumfries-shire footprints were listed and, in many instances, figured. Haubold considered the ichnogenera proposed by Harkness in 1851 (*Batrachichnis* and *Saurichnis*) to be synonyms of the senior *Chelichnus*: specifically he considered *Batrachichnis stricklandi* Harkness to be synonymous with the same author's *Chelichnus* (ex *Labyrinthodon*) *lyelli*, and *Saurichnis acutus* Harkness to be a junior synonym of *Chelichnus duncani* (Owen). Harkness' ichnogenus *Chelaspodos* was also thought probably to be synonymous with *Chelichnus*, though the validity of its type-species was not questioned. *Chelichnus ambiguus* Jardine 1853 and *Herpetichnus robustus* Delair 1966 were both transferred to the ichnogenus *Laoporus* Lull; the other species from Dumfries-shire were retained in the ichnogenus *Chelichnus*.

All these footprints were considered to be those of caseasaurs (edaphosaurs), a group of early, clumsy herbivorous reptiles which flourished in the Late Carboniferous and Early Permian [306, pp.36–41]. In contrast, Haubold felt unable to suggest any systematic assignment for the trackmakers responsible for *Actibates triassae* Jardine and *Cardiodactylum permicum* Delair —

names which, incidentally, well reflect the changing interpretation of Dumfries-shire stratigraphy in 150 years of study! [306, pp.90—91].

Midlothian

The second discovery of footprints in Scotland was, rather unexpectedly perhaps, in a quarry in the environs of Edinburgh — Craigleith quarry, in the western suburbs of the city. The only published description of these is in George Fairholme's "General view of the Geology of Scripture" (1833); as already mentioned, Fairholme commented briefly on the Corncockle Muir tracks but, confessing himself entirely ignorant of that locality, proceeded instead to give an account of "impressions found in the Craigleith freestone, and of which casts have been placed in the Museum of the Royal Society of Edinburgh" [40, p.341]. The Craigleith Sandstone, a local rock unit within the Lower Oil Shale Group (Carboniferous: Visean), was worked extensively for building stones in the nineteenth century; Fairholme described and figured the occurrence of a fossil tree found in 1830 in this quarry [40, pp.328—330, unnumbered fig.]. The footprints are not illustrated, but are described at some length; Fairholme was avowedly a Catastrophist and explained the preservation of the footprints quaintly:

". . . in the present course of things, the footprints of any animal, passing over the smooth sands on the ebb tide, could not long resist even the gentlest action of the waves, because the waters of the ocean, in their natural state, are so nearly pure, and free from sediment, that the progress of the secondary formations is so slow as to be almost imperceptible to our view. But, at the awful period of which we are now treating, the seas must have been . . . heavily charged with their preternatural burden; and every successive tide must, consequently, have deposited some additional beds upon the growing earth. In this manner alone . . . can we account for the preservation of those animal footmarks now discovered between the strata." [40, p.343]

His Catastrophist thinking not only occasioned a further question which he found it necessary to answer, but also indicated that he adopted that theory with reservations:

"But it will naturally be asked, where was the animal to come from at a time when the whole living kingdom was in the act of being destroyed; or, (if the footmarks were made, as appears most probable, on the *decline* of the Deluge), when all had already perished? To this we reply, that we have here the most positive evidence, that *all* had not perished when these sandy formations were being so rapidly deposited. At whatever period of the Deluge this deposit took place, we see, that at least a few individuals, of the animal world, were lingering out a miserable existence, perhaps, preserved for weeks and months on those same vegetable islands which we have seen were being deposited in the immediate neighbourhood, and, now exhibited, in the form of coal. If the animals in question were of the tortoise or turtle tribe, as has generally been conjectured, and, consequently, of an amphibious nature, we can have the less difficulty in finding a solution for this interesting problem; for, in considering the fossil remains of the natural inhabitants of the sea, we have before found it probable, that by no means a general destruction took place among this extensive class at the time of the Deluge." [40, pp.343—344]

He summarised his observations and conclusions as follows:

"These *fossil* footmarks have all the appearance exhibited on a recent *sand-bank*. They, in some instances, indicate a short and shuffling gait, with the feet pressing *outwards*, and are such as we can suppose an amphibious animal to produce. Had the marks occurred in *clay*, instead of in *sand*, we can suppose the air to have completely *hardened* the impression, so as to have preserved it for a long time before being covered up. But such is not the case; and we can, therefore, have no manner of doubt that they were occasioned by some animal coming *ashore on a sand-bank left dry by the tide*; and that the returning waters, heavily charged as they must have been, by diluvial sediments, immediately covered up the former strata, and thus preserved entire those most interesting and solitary indications of a still living antediluvian race." [40, pp.344—345]

Clearly the Craigleith footprints must have been of great interest; unfortunately, Dr. Charles D. Waterston (written communication, 1973) reports that they were not among the specimens passed by the Royal Society of Edinburgh to the Royal Scottish Museum in the second half of the nineteenth century and cannot now be traced.

The only other published record of footprints from Midlothian is even more tantalising; it is contained in an address by the great Scottish geologist Hugh Miller, given on his retirement from the Chair of the Royal Physical Society of Edinburgh and published as an appendix to the posthumous seventh edition of his classic work "The Old Red Sandstone". In the course of a discussion of bones of reptiles from the Scottish Coal Measures, Miller reported that:

"The *Parabatrachus colei* of Owen has been found in the coalfield near Carluke; and the footprints of a much larger reptile detected in our Dalkeith coalfield by Mr. Henry Cadell, the experienced and intelligent mineral surveyor of His Grace the Duke of Buccleugh." [41, pp.366—367]

No further discoveries of footprints from this county have been reported during the ensuing century.

Morayshire

Further discoveries of footprints in the Scottish red sandstones did not occur until 24 years after the first reports from Dumfries-shire. It was only in 1852 that Captain Lambart Brickenden discovered in Mason's Heugh quarry, on the estate of Major Cumming Bruce at Cummingstone near Elgin, a slab exhibiting no less than 34 footprints. The track was immediately recognised to be that of a quadruped, with fore feet markedly smaller than hind, together with intermittent tail-drag marks [43]. His illustrations show the whole slab, but the details of particular prints are not clear; new photographs of his specimen are here attached (Fig.3). Since the sediments from which the slab was derived were then considered to be Old Red Sandstone (Devonian), the find appeared to be one of greater importance in terms of vertebrate history than was in fact the case.

Following Brickenden's discovery, further blocks with footprints were

Fig.3. Footprints from Cummingstone, Morayshire, collected by Capt. Lambart Brickenden (1852). Length 1.86 m. (Specimen GSM 113445). Top: the whole slab; bottom: detail. Photo courtesy of the Director, Institute of Geological Science, London.

obtained from the quarry by two local gentlemen, Mr. Patrick Duff and Mr. Alexander Young; the latter had also acquired Brickenden's specimen. (It is now lodged in the collections of the Institute of Geological Sciences, London.) Footprints had also been obtained from the Clashan quarry, near Covesea, and from a quarry at Greenhow by a Mr. Anderson, apparently the owner of both these quarries; and in addition, vertebrate footprints were displayed in "a block quarried at Lossiemouth, and partly dressed for the step of a stair", which was secured by the Rev. G. Gordon for the Elgin Museum. These supplementary details are all contained in a discussion of the stratigraphical relationships of the Morayshire sandstones, presented to the Geological Society of London by Sir Roderick Murchison in 1859 [51]. Murchison had accompanied the Rev. Gordon in a tour of the district; he noted that footprints were to be found widely in outcrops and quarries on the coast ridge between Lossiemouth and Covesea. The strata were indeed beginning to excite considerable attention, since bones and scutes of reptiles had now been found in the quarries around Elgin. The age of the beds was still a matter for doubt; Murchison first of all hesitated between a Devonian or lowest Carboniferous date and finally, in a postscript to his paper, admitted the possibility

that they might be more correctly assigned to the New Red Sandstone (Permian—Triassic) rather than to the Old [51].

Murchison's paper was immediately followed by a description by Thomas Henry Huxley of reptilian remains from Cummingstone near Elgin [48]. They were attributed to the species *Stagonolepis robertsoni* (Agassiz) Huxley, and an account of the footprints found in the same quarry was appended. Huxley noted that, although footprints of very variable size were evidenced, "only two were so clear and distinct as to satisfy my mind that they fairly represented the position of the foot". These were illustrated and described. They formed part of what was clearly the trail of a quadruped; they were plantar (flat-footed) and comparable with *Chelichnus*, the fore and hind feet being markedly different in size. Rather oddly, Huxley considered the larger prints to be those of the *fore* feet! He concluded guardedly: "As to whether they were produced by *Stagonolepis*, I will only say that I see no grounds for asserting that they were not". *Stagonolepis* he considered to be a crocodilian [48]. This conclusion is understandable, for Huxley's study was based on fragmentary remains and, though the genus and its allies are now referred to a different group of reptiles (the Aetosauria) they are strikingly crocodiliform in armour and general structure; however, the aetosaurs appear to have been herbivores and were certainly a terrestrial, rather than an amphibious, group.

Also in 1859, in a brief note, S. H. Beckles described some major excavations he had undertaken in a search for footprints in a quarry at Covesea, near Elgin; this work had been most successful and a large number of slabs had been sent to London. (Beckles' excavations were also incidentally mentioned by Murchison [51]). The footprints encountered were mostly of bipeds and were very variable in number of digits impressed (2—5) and in size, impressions of footprints apparently formed by young and old members of the same species being noted [42]. A fuller account promised by Beckles was never forthcoming; the present whereabouts of the slabs he collected is uncertain.

The stratigraphy of the Morayshire rocks containing footprints and reptilian remains was discussed at some length by Harkness in 1864, who noted the occurrence of footprints at Lossiemouth and also discussed footprint records from Ross-shire. Although recognising that the reptilian remains in these beds were comparable to those from the Triassic, Harkness remained convinced of their Old Red Sandstone date [45].

In 1877, Huxley published a more extended account of the Cummingstone reptile *Stagonolepis* and again discussed the footprints, presenting better drawings of the footprints he had described earlier and proposing the name *Chelichnus megacheirus* for them. In addition, a new slab, covered with footprints was figured; but, although Huxley furnished large-scale drawings of two individual imprints, they were not clear enough to deserve a new name [48]. Huxley's specimens were listed in Newton's catalogue of the Triassic fossils in the Museum of the Geological Survey at Jermyn Street (1904) [52]; they survive in the collections of the Institute of Geological Sciences.

The Morayshire footprints received incidental mention in two papers by W. Jolly, published in 1876—78 [49, 50]; the latter paper included a mention of footprint-bearing strata in Burghead and Bishops Mill quarries. The reptiliferous sandstones were discussed at some length by the Rev. Gordon in 1893 [44]; and the occurrence of *Chelichnus megacheirus* at Cummingstone was noted, in a listing of fossil vertebrates from the Moray Firth area, by John A. Harvie-Brown and Thomas A. Buckley in 1895 [46, p.280]. In 1909, George Hickling firmly included them in his review of "British Permian Footprints" illustrating some of the tracks and noting their similarity to Nottinghamshire footprints; in addition, he mentioned new finds in quarries at Bishops Mill, Elgin [209]. The zoologist D. M. S. Watson agreed with Hickling's opinions in papers published solo in 1909 [53] and jointly with Hickling in 1914 [54].

Despite the richness of this ichnofauna, it has gone entirely unstudied in the last sixty years; the fate of specimens originally lodged in various private collections is not clear and no account has yet been published of the footprints in Elgin Museum. Although these beds are today considered to span the Permian and Triassic, some doubt subsists about their precise stratigraphic equivalence; certainly the potential afforded by the footprints for correlation with English and German Permo-Triassic sediments deserves to be explored.

Ross-shire

Footprints were first discovered in the sandstones of Ross-shire, across the Firth of Tay from Morayshire, by the Rev. G. Campbell of Tarbat in 1862. They were found in thinly bedded sandstones in the cliff at Cambus-Shandwick, north of Portmahomack. The specimens were extracted and taken to the Manse at Tarbat; and an account of them was presented to the Geological Society by two of Campbell's clerical colleagues, the Rev. G. Gordon (Murchison's friend) and the Rev. J. M. Joass, in 1863 [57]. Unfortunately, the footprints were neither illustrated nor adequately described. The strata were considered attributable to the Old Red Sandstone, as at that time were their equivalents in Morayshire.

Harkness, in 1864, observed that footprints could be found from various points on the coastal section between Cambus-Shandwick and Portmahomack and that the beds from which they came exhibited ripple marks, shrinkage cracks, raindrop impressions and the tracks of Crustacea [45]. The Ross-shire footprints were mentioned by Jolly in 1876 and 1878 [49, 50], by Gordon in 1893 [44] and, without illustrations, by Hickling in 1909 [209], but they have never been fully described. The vertebrate character of these impressions was questioned by J. A. Harvie-Brown and Thomas E. Buckley, in their review of vertebrate fossils from the Moray Firth area [46, p.273]; and this question cannot presently be resolved, since no specimens from this area are known to be in any museum collections.

Roxburghshire

In a note appended to an article by Robert Harkness, J. W. Salter recorded some tracks from the Silurian of Binks, Eskdale. The tracks, named *Protichnites scoticus*, were considered from the outset to be those of invertebrates, probably Crustacea [59], an opinion which today seems entirely correct. They are mentioned here only because some later passing references, e.g. by Owen [58] and Delair [11], appear to suggest a vertebrate affinity for the tracks; in the latter instance, this is entirely a consequence of textual ambiguity. No true vertebrate tracks have been recorded from this county.

Ayrshire

In 1889, one John Smith reported that, when examining "the fine section of red Calciferous Sandstone" (Lower Carboniferous) "which is exposed in the cutting of the Ardrossan and Largs railway, situated about two and a quarter miles north of West Kilbride, I was not a little surprised to discover a double row of what appeared to be the fossil footprints of some animal". [1, p.201]. They were preserved on the undersurface of a sandstone stratum dipping at 80°; in size, they were about 3 in. long by 2 broad and deeply impressed to about half an inch. The section also exhibited ripple marks, sun cracks, worm tracks and what were taken to be rain pits. Unfortunately, the footprints were too much abraded, as a consequence of prolonged weathering, for accurate study [1].

In 1909 Smith published a small book, "Upland fauna of the Old Red Sandstone Formation of Carrick, Ayrshire", one of the rarest in ichnology; despite illustrations and descriptions of 17 genera and 43 species, this work has virtually escaped attention. All of the structures described appear, however, to be produced by invertebrates or of inorganic origin [2]; the tracks he described earlier were not again discussed, even though it was by then recognised that they too were of Lower Old Red Sandstone date [see 56, p.140]. Smith's original figure [1] provides no convincing evidence that the structures recorded were of organic origin; if they were indeed vertebrate tracks, they are among the oldest on record, but confirmation is unlikely ever to be forthcoming.

Nairn

In Gordon's (1893) discussion of the Elgin reptiliferous sandstones [44, p.243], it is noted that:

> "At the Nairn quarries, there are many remains of "Old Red" fish. From these quarries, there is a block of whitish sandstone, now in the Elgin Museum, which shows numerous marks, apparently reptilian footprints."

This slab has never been fully described, nor have any further records of footprints from Nairn ever been published. In view of the extreme unlikelihood of vertebrate tracks being preserved in Devonian rocks, a re-examination

of the slab (if it survives), although desirable, would probably invalidate this record.

Caithness

Around 1900 a block of fine-grained sandstone, yielding the mould and cast of a tridactyl footprint, was found in a peat-bog at Kiess, Caithness; the mould and cast were subsequently presented to the British Museum (Natural History) by Sir Francis Tress Barry. No description of it has hitherto been published.

The Devonian date tentatively assigned to the slab in the British Museum catalogue is certainly incorrect, for the footprint (Fig.4) is clearly that of a

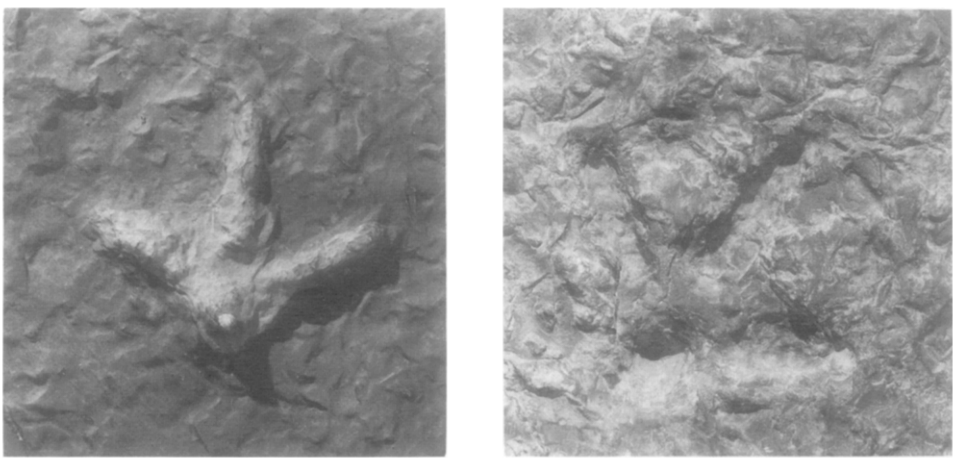

Fig.4. The tridactyl footprint from Kiess, Caithness. Left: cast; right: mould. Photo courtesy of the British Museum (Natural History), London.

small saurischian dinosaur; indeed, it shows close morphological accord with *Anomoepus minimus* Hitchcock, an ichnospecies originally described from the Triassic of the Connecticut Valley. However, as similar footprints are known from Cretaceous rocks and since Jurassic footprints are very poorly known, all that can be said with confidence is that this is a slab of a Mesozoic sediment. No Mesozoic rocks survive in Caithness; however, Jurassic rocks crop out not far to the south, in Sutherlandshire, and are present under the North Sea off the northern coast of Caithness. Southward transportation of the block by ice during the Pleistocene seems a likely explanation for its turning up in the peat-bog at Kiess; unfortunately, the block shows no ice scratches or other indications of glacial transport, so this theory is wholly speculative.

Orkney Islands

Between 1927 and 1929, a team of officers of H.M. Geological Survey undertook the first detailed mapping of the Orkney Islands. Their report on the area, published in 1935, incorporates an illustration [56, p.141] of some

remarkable tracks discovered in the Hoy Sandstone of the Upper Old Red Sandstone (Upper Devonian) at a locality in the Burn of Redglen on the west side of Ward Hill, Isle of Hoy, here reproduced (Fig.5.) The tracks are quite small, with a total breadth of around 3 cm; they consist of a broad central drag-furrow, on either side of which are distinct foot impressions.

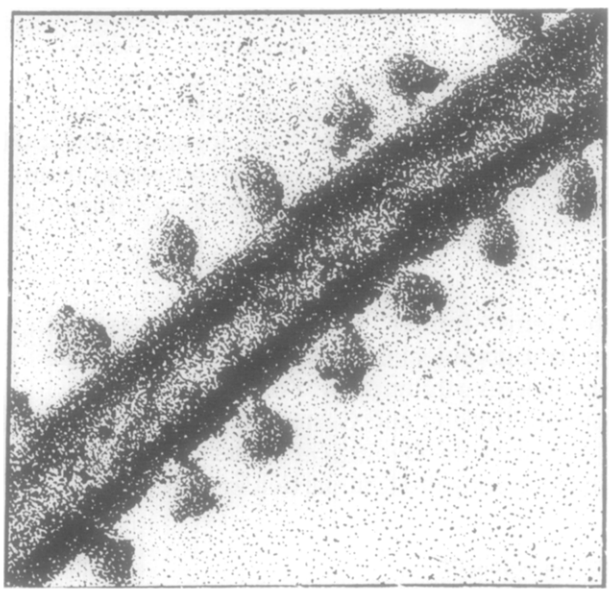

Fig.5. The trackway from the Devonian of Hoy, Orkney Islands. Natural Size. (Reproduced by courtesy of the Director, Institute of Geological Sciences, London.)

This was the time of early venturings of vertebrates onto land, with rhipistid fishes able to drag themselves laboriously between pools in the beds of drying-out rivers and with the first amphibians, the ichthyostegalians, dragging themselves along the shores of seas and rivers scarcely less laboriously. These tracks may well be those of such an early venturing; the broad central mark looks like a belly-trace and the imprints at the sides could well be made by fin-like feet. In 1937, the distinguished palaeoichthyologist, T. Stanley Westoll, commented that they were "rather suggestive of a very primitive Tetrapod of sprawling, wriggling gait and very short stride, the hind feet being planted in the tracks of the fore feet; the fore and hind limbs may have been several times the length of the stride apart" [55, p.32]; but he stressed that this interpretation was "of course, quite uncertain". A fuller study of the tracks, to confirm or refute his hypothesis, can only be made when further specimens are collected, since the original tracks are apparently not preserved in the collections of the Geological Institute.

ENGLAND

General introduction

In treating with the history of the study of vertebrate footprints in England, the dating of the specimens, almost consistently a difficulty for Scottish stratigraphers, is not such a problem; in almost all instances, the age of the footprint has been known with fair precision from the very outset. It is therefore convenient to consider the history of English vertebrate ichnology in terms of the geological systems from which the specimens were obtained. Since Triassic finds considerably predate all others and are much the most numerous, they are dealt with first. The other systems are then treated in stratigraphic order. Within these broad headings, the finds are again discussed by county, save in the case of the very few finds of Triassic footprints from southern Lancashire, which are for convenience considered along with those from Cheshire.

Triassic footprints

Throughout this section, the terms "Bunter" and "Keuper" are used in their traditional English sense; stratigraphical comparability with the type German sections is by no means necessarily implied. For recent ideas on stratigraphical correlation between England and Germany, symposium papers presented in the "Quarterly Journal of the Geological Society of London", vol. 126, pts. 1—2 (1970) should be consulted, in particular that by Thompson [143].

Cheshire and southernmost Lancashire

Fossil vertebrate footprints may have been first found in the Cheshire Triassic in 1824, the same year as their presumed discovery in Scotland (see p.267), but it was not until fully fourteen years later that their character was perceived. Their first recognition was in the early part of June, 1838, when workmen in quarries in the Triassic (Keuper) sandstones at Storeton Hill, Wirral, discovered, on the undersides of sandstone blocks, casts in high relief of what they at first believed to be human hands. The discovery was made known to the Natural History Society of Liverpool, which thereupon appointed a committee to draw up a report on the footprints for presentation to the Geological Society of London. The hand-like footprints were immediately recognised to be of the same kind as some described from Germany by J. J. Kaup (1835), which he had named *Chirotherium*, "hand animal" [311]*.

* Kaup originally formulated two alternative names, *Chirotherium* and *Chirosaurus*, "hand beast" and "hand reptile"; though the latter name was in intermittent use until the later nineteenth century, the former, less appropriate name unfortunately has taxonomic priority. Kaup's Greek transliteration was later corrected and the spelling *Cheirotherium* proposed instead; though this spelling has also been widely used, its adoption contravenes Article 32 of the "International Code of Zoological Nomenclature" and is thus invalid. It is retained here only in direct quotations from earlier works.

The first published account of these footprints was apparently an anonymous write-up of a lecture given by Professor R. E. Grant to the Liverpool Mechanics' Institution; this appeared in the "Liverpool Mercury" in August, 1838 [63] and was reprinted in full during the following year in the "Annals and Magazine of Natural History" [64]. (Earlier newspaper accounts may, however, exist.) Grant's lecture was delivered as he stood alongside a footprint slab, presented to the Institution by a Mr. Tomlinson. He noted that there were at least two footprint-bearing layers in the quarry, about two feet apart, with a possible third situated slightly lower. In each instance, they were located immediately on top of a thin clay parting:

"The prints of the feet have always been first made on the upper surface of these thin layers of clay, which have but imperfectly communicated them to the surface of the rock below, but have given most perfect casts of these impressions to the superincumbent rocks." [63]

In addition to the *Chirotherium* prints (of which trackways at least 30 ft. long had been noted), there were also:

". . . numerous short club-feet, with large broad claws of tortoises; some feet with the toes and claws more elongated and webbed of *emydes*, or waddling chelonia; many with the long free toes and slender claws of lizards; some approaching in form and gait to *ornithichnites*, but without hind toe, and with the anterior toes approximated and collapsed; and some resembling the long tapering feet of frogs, advancing by alternate motions of their hind webbed-feet along: — but all agreeing with the reeds and branches of trees, in indicating a great river or estuary opening remotely into the sea, and that the *chirotherium* (sic) itself may have been also semiaquatic like the crocodiles and emydes of existing shores." [63]

Grant described the *Chirotherium* tracks carefully and stressed his opinion that these were not tracks of mammals but of reptiles, probably crocodilian in character. His mentions of the other tracks are confusing and over-brief, but they do indicate that the diversity of types of tracks at Storeton was recognised from the outset.

Reports of the discovery were subsequently presented to the Geological Society of London on the evening of November 7th, 1838. It is not clear who delivered the principal paper, since the record of the meeting merely states that "An account . . . communicated by the Natural History Society of Liverpool, and illustrated with drawings by John Cunningham, Esq., was then read". Authorship and presentation of the paper have since tended to be attributed to Cunningham (for example by Swinton [320]), but it is quite probable that the paper was written by other hands and it may well have been read by the Secretary of the Geological Society! On present evidence, one can only attribute the *illustrations* to Cunningham with any confidence, particularly since the account refers to the authors, not author!

It was noted that the hand-like impressions were those of the hind foot (pes); impressions of the hind foot were very much more common than those of the fore foot (manus). The tracks were extensive:

"Traces of one animal have been observed in a continuous line on a slab ten yards long. The length of the step varies a little, but in general, the distance between the point of the second toe of one hindfoot and the point of the hindfoot immediately in advance, is between 21 to 22 inches. Each forefoot (manus) is placed directly in front of the hind, and the thumbs of both extremities are always towards the medial line of the walk of the animal." [115, p.14]

Detailed measurements for the impressions were quoted: fore foot lengths of 4½ in. contrasted with hind foot lengths of 9 in. The Liverpool naturalists envisaged a complex mode of progression, on the supposition that the digit conjectured to be the thumb was really the first digit:

". . . the animal must have crossed its feet three inches in walking, for the right fore and hind feet are placed 1½ inch on the *left* side of the median line, and the left fore and hind feet 1½ inch on the right side of the same line." [115]

Their basic premise was false and pressed the human analogy too far; the opposed digit in reptiles is in fact the fifth digit, equivalent to our little finger, and the gait is in fact a straightforward quadrupedal step in which all four feet are impressed. In quadrupeds the sequence of walking or running movement always begins with one hind foot, followed by the fore foot of the same side, then by the hind and fore foot on the other side. Two or three feet are repeatedly in simultaneous contact with the ground in rapid movement, three or four in slow movement. Walking tracks always have right manus alongside left pes and vice versa; the impressions of the right manus and pes and of the left manus and pes are generally quite far apart. In running tracks, however, the impressions of the right manus and left pes become separated, whereas the left pes impression approaches, and may even be superimposed upon, that of the left manus. In jumping tracks, all four impressions lie close together, at a considerable distance from the next group of four impressions; rather surprisingly, no jumping tracks have yet been reported from the fossil record.

The greater abundance of hind foot impressions at Storeton was recognised but not explained. It certainly results very largely from the fact that they are larger than the fore foot impressions and, since they carry a greater proportion of the body weight, more deeply impressed; but a secondary cause is that these reptiles, though generally progressing on all four feet, were capable of walking on the hind feet only. (In bipeds left and right impressions alternate, the impressions being of constant size: the impressions are never directly alongside one another.) It must be remembered that, in 1838, the former existence of reptiles capable of adopting a bipedal gait, or even habitually bipedal, was not even suspected, so it is easy to understand why this possibility never occurred to the Liverpool naturalists.

The footprints were not all of *Chirotherium* type:

"Many large slabs are crowded with casts in rilievo, some of which are supposed to have been derived from the feet of Saurian reptiles, and others from those of tortoises. Occasionally the webs between the toes can be distinctly traced." [115]

Moreover, this first paper was followed by the reading of a note by Mr.

James Yates, describing "four differently characterised footprints" from Storeton, "each of which is distinct both from the casts of the Chirotherium and the web-footed animal mentioned in the preceding report". Unfortunately, Yates' note, which was illustrated by sketches, received only the briefest of mentions [151] and was destined never to be published in full.

The third ichnological paper presented at this historic meeting was a description by Sir Philip Grey Egerton, Bart., of some footprints collected in 1824 near Tarporley, Cheshire, from an unascertained locality. Egerton was, like his friend the Earl of Enniskillen, almost exclusively a collector of fossil fishes; indeed, his obituary notice described him as "pre-eminent in fossil ichthyology" [98]. It is surprising that the footprints were even *in* his collection and the fact that, though he had had them since 1836, he had not recognised their true nature till attention was focussed on fossil footprints by the Storeton discovery, was probably because they were so very marginal to his principal interests. The prints were of much greater size than those reported from Storeton or, earlier, from Germany; Egerton therefore proposed a new name, *Chirotherium herculis*, which echoed their special character, "in compliance with the adage *ex pede Herculem*" [96].

It should be noted that, though their publication date is often incorrectly cited as 1839 (e.g. by Swinton [320]), the three papers all appeared in the "Proceedings" of the Geological Society before the end of 1838. All three were republished in the "London and Edinburgh Philosophical Magazine" in January, 1839 [96, 115, 151]. A sheet of lithographs of the footprints and of various other impressions was published by the Liverpool Natural History Society at about this time: the footprint illustrations are here reproduced (Fig.6). The original specimens were presented to the Royal Institute, Liverpool; they were subsequently purchased by the Corporation of Bootle and deposited in the Free Public Museum of that town, where they are still preserved.

Within a few days of the London meeting, on 16th November, 1838, J. Lawrence read a paper on the Cheshire discoveries to the Leicester Literary and Philosophical Society; however, this does not appear to have been published till 1841 [112]. Before this, letters sent in 1839 by Sir Philip Egerton and Mr. J. Taylor, describing casts of *Chirotherium herculis* "at the house of Mr. Potts in Cheshire", had appeared in the "Proceedings of the Geological Society" [97].

In 1840, James Yates reported to the British Association, at its Glasgow meeting, some footprints from a new Cheshire locality:

"For more than half a century a stone quarry has been worked in Rathbone-street, Liverpool; but only within a few weeks have any traces been observed in it of organic existence On my way to the Meeting of the British Association, I had occasion to stay a short time at Liverpool, and was informed by Mr Higginson, a surgeon in that town, that he had found in this quarry footsteps of the same kind which were discovered about two years ago at Stourton, in Cheshire. I accompanied him to the spot, and found the appearances as follows. The strata are moderately inclined, and of so great thickness as to be well adapted for building. The workmen are at this time hewing out of them a set of pillars

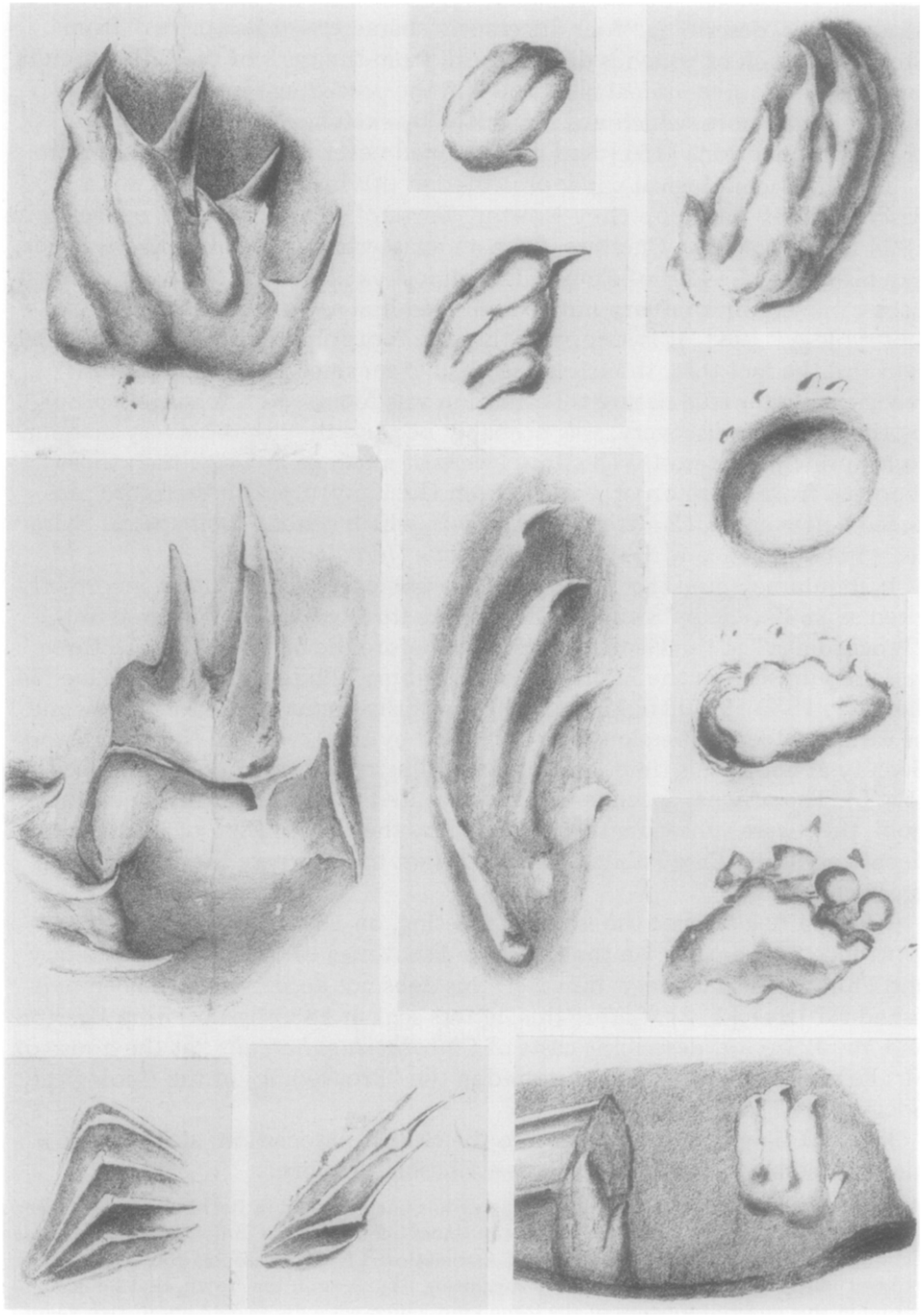

Fig.6. Lithographs of Triassic footprints from Storeton, Cheshire, prepared by Murry Dicks for the Liverpool Natural History Society around 1838. (From an original in the collection of Dr. J. C. Harper, Liverpool.)

twenty feet long, intended to form the colonnade of a public edifice. These thick strata alternate with others which are very thin, and on which the ripple-mark is sometimes seen. Lumps of soft clay of the form of pebbles, such as are still formed every day on the shores of the Mersey, are found imbedded in the sandstone, and thin seams of clay are interposed between the sandstone strata. The footsteps are found on turning up the broken pieces of one of these strata; for they occur on its under surface, and are in fact casts, not original impressions. This under surface rests upon a seam of fine clay about one quarter of an inch in thickness. Without the intervention of the clay which has been deposited between the beds of sand, it is manifest that neither ripple-marks nor footsteps would have been preserved. But it appears that, soon after the deposit of a thin bed of clay upon the soft sand, amphibious quadrupeds, probably allied to crocodiles, monitors, or other saurians, traversed the shore of the then existing river, and left their footsteps impressed upon the clay. The water having again overflowed the shore, deposited a bed of sand, filling the impressions of the animals' feet, and consequently, on the induration of the sand and its conversion into stone, producing those casts which are now discovered." [152]

In the following year Gideon Mantell, in an account of fossil turtles from the Chalk, noted that chelonian tracks had been found at Storeton quarry [119]; no details were given of the specimens on which this comment was based. In 1842, when the British Association for the Advancement of Science met for the first time in Manchester, John Hawkshaw reported the discovery of footprints at a new Cheshire locality — the sandstone quarries at Lymm. He noted that these included *Chirotherium* tracks and "footprints of birds" [105]. During the following year, a French account of his observations was published [106] and they were discussed by G. W. Ormerod, who considered the *Chirotherium* imprints to be "Labyrinthodont footprints". Ormerod also reported discoveries of similar tracks at Delamere Forest and Weston near Runcorn; his paper was originally published in 1843 and was republished in 1868 [131], but neither edition gives illustrations or adequate descriptions.

In 1846, Dr. J. Black reported the discovery of four different types of tracks, which he designated A—D, in a quarry at Over Hill, Weston [92]. The slab bearing these imprints was presented to Manchester Museum and was ultimately redescribed, seventy years later, by F. T. Maidwell [118]. A tridactyl imprint was discovered in the neighbouring quarry of Weston Point, 1½ miles west of Runcorn, by Robert Harkness in 1850 [101]. Harkness considered the rocks cropping out in this quarry to be assignable to the Bunter; however, although rocks assigned to the "Bunter" *sensu anglico* do indeed outcrop at Weston, they are not quarried, so this stratigraphical attribution is clearly mistaken. The footprint had originally been found by E. W. Binney and was therefore given the ponderous new name *Plesiothornipos binneyi*; however, it has never been illustrated and the whereabouts of the type specimen is not known. In 1852—53, R. Rawlinson described to the Geological Society some further tracks from Lymm; their character is so incompletely described as to render this paper entirely useless [133, 134].

A track from Storeton, presented to the British Museum "by J. Tomkinson Esq.", was noted by Mantell in 1851, but Mantell was much more interested in North American footprints and gives it only passing mention [121, pp.62,

63]. In the same year the footprints from "Storton" were mentioned in the revised edition of Richardson's "Introduction to Geology" [135]; they were again mentioned, in a lecture to the Ashmolean Society of Oxford, by Strickland in 1852 [36] and were discussed briefly by d'Archiac in 1860 in his massive review of progress in geology between 1834 and 1859 [69]. Mitchener, in an account of the "Stourton" quarries published in 1860, mentioned "Labyrinthodont pachygnathous footprints" [123], echoing a current theory which ascribed the *Chirotherium* tracks to those ponderous amphibians — an unlikely ascription in view of the much more uniform limb size of labyrinthodonts.

The Liverpool Natural History Society progressively lost support and, in 1844, merged with the city's Literary and Philosophical Society; John Cunningham thus became a member of the latter Society. On November 17th, 1845:

"Mr. Cunningham exhibited an impression from Storeton Quarry, which he considers to be that of a large Tortoise." [93]

In 1846, an excursion was made by the Literary and Philosophical Society to Storeton Hill, apparently under the leadership of Dr. A. Hume; no reference can be found to this in the Society's Proceedings, but it seems that a three-toed print was found. At the meeting of the Society on 7th February, 1848:

"Mr. Cunningham exhibited a cast of some impressions found on a stone taken from the west side of Storeton Hill; the original could not be procured. At one part there were impressions of two feet, each consisting of a sort of boss or heel with three long slender toes, probably webbed; at another, there were marks which led to the belief that the foot had been cased in a shell; at another, an impression left, it was supposed by a medusa." [95]

Lithographic reproductions of these casts, together with reproductions of a footprint discovered in a road cutting at Flaybrick Hill, Birkenhead, were prepared and published in the "Proceedings" for that year (1848); since they are the rarest of all Cheshire footprint illustrations, they are here reproduced (Fig.7). The slab from Flaybrick Hill was lodged in the Museum of Liverpool's Royal Institution.

Around 1861, stone was obtained from Storeton quarry for the building of a new church, Christ Church, close by in Higher Bebington. A slab exhibiting a chirotherioid cast was incorporated into the structure of the church porch: it has since attracted a great deal of attention and is locally named "The Devil's Toenail" — a singularly irrelevant name (Fig.8). This is surely the only occurrence of a fossil footprint in ecclesiastical architecture!

In 1859, a new society was formed to "investigate the structure of the Earth, the character of its past inhabitants and the changes now in progress upon its surface" — the Liverpool Geological Society. The real founder of the Society was George H. Morton (1826—1900), who was its Secretary from its inception till 1885, save for the period 1868—1870 when he was its President; he finally relinquished the secretarial office to serve a second term as

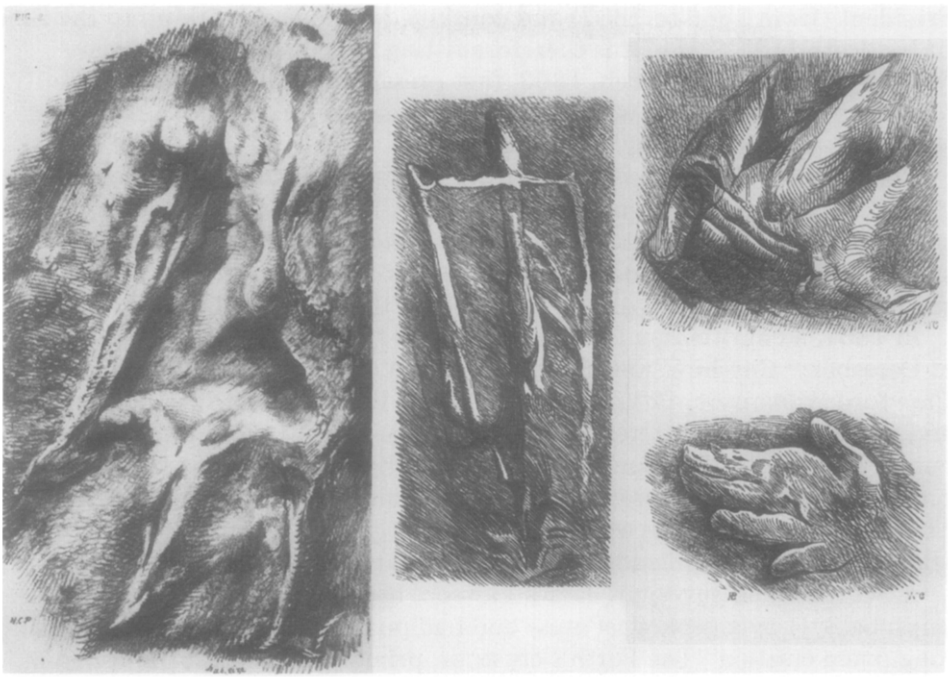

Fig. 7. Lithographs of Triassic footprints from Storeton and Flaybrick Hill, Cheshire, published by the Liverpool Literary and Philosophical Society in 1848.

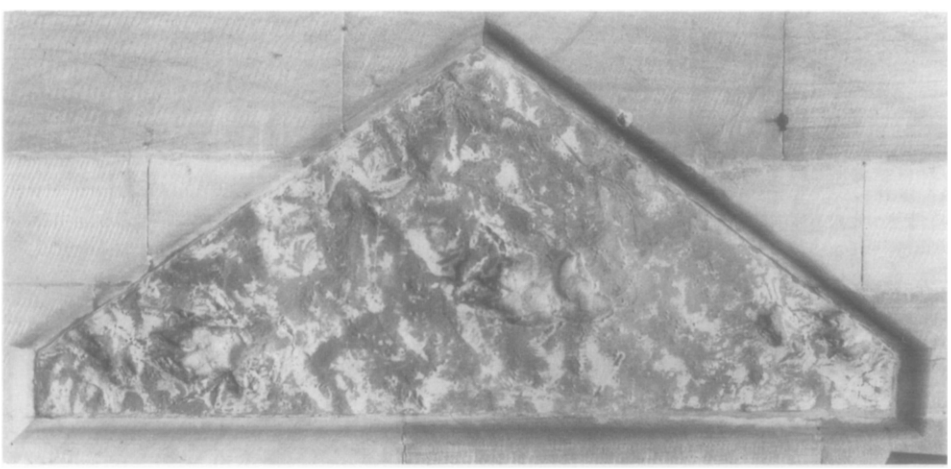

Fig. 8. "The Devil's Toenail": a hind print of *Chirotherium storetonensis* incorporated into the porch of Christ Church, Higher Bebington, Cheshire. (Photo: B. J. Studios.)

President (from 1886 to 1887) and continued geological work up to the time of his death [107, 137]. It is therefore fitting that it should have been Morton who, on 17th March, 1863, first presented a paper on vertebrate ichnology to the Society which was to become the prime British focus for such studies in the ensuing half-century.

The tables of dimensions given earlier by Egerton had already made it clear that there were dimensional differences, not only between the type species *C. barthi* and Egerton's giant *C. herculis*, but also between both these species and the other forms described from Storeton. Morton now conferred the new name *Chirotherium storetonense* on the latter [125].

In 1867, a chirotherian footprint from the base of the Keuper Sandstone at Daresbury, Cheshire, was described and excellently figured by William Crawford Williamson, Professor of Botany at the University of Manchester and a man with wide interests in natural history [150]. This print was discussed in detail by Swinton [320, pp.448—449] and thus does not merit prolonged description here; no taxonomic name has yet been attached to it. The Cheshire occurrences were mentioned in a general account of the Permian and Triassic of the Midlands by Edward Hull, published in 1869 [109].

A Scottish land surveyor, James Lawson, had been earlier visited (rather improbably!) by a geological muse and had poured out his inspiration in a long poem entitled "The Earth's crust; or, primordial scenes", published in 1863. It contains the following passage, well worthy of a fellow countryman of the immortal William McGonagall:

"The upper flight three stages so contains
Which form the new red sandstone and its gains.
Among its fauna reptiles had abode
And lithograph'd. Their footprints, as they trode
Upon the sandstone, and the beds of clay,
Are most distinctly seen up to this day;
And, by admeasurement, are found to be
In inches eight by five, and four by three;
Imprinted so in pairs, these do appear
With larger footprints, inch and half in rear.
Then, 'twixt the pairs are fourteen inches space,
Describ'd so plain along the line of trace.
In pairs the footprints follow in right line,
And both the wide and narrow steps define,
Which show alternately on right and left,
The great toe, like a thumb, of nail bereft,
And inwards bent, and each step prints five toes,
So like the human hand that sameness flows.
And, though the fore feet smaller than the hind,
Are like in form and sim'larly defin'd.
Their teeth, so conical and curv'd do show
Striations on the surface to and fro,
The dentine of the which presents to view,
In transverse section beauties old and new;
The microscope detects the windings, they
So sinuous do trace and wend away

And bear a semblance to the human brain,
Which shows lab'rinthic foldings clear and plain
From whence derived the name lab'rinthodon
Of this mysterious genus dimly shown." [113, pp.68—69]

Unfortunately for the earnest poet, the labyrinthodont affinities of *Chirotherium* were firmly discounted by Professor L. C. Miall in 1873, in a paper read to the British Association at Bradford. His perfectly correct judgement was that "there is not a single distinctively Labyrinthodont feature about *Cheirotherium*" and he suggested that these were instead the footprints of a dinosaur [273]. Nonetheless, the labyrinthodont idea still hung around for many years to come.

In 1880, after the Liverpool Geological Society had firmly resisted attempts to create a junior section to include younger students and beginners, a second society was formed in the city — the Liverpool Geological Association. This attracted strong initial support and was soon organising its own programme and producing its own journal. The elder Society seems to have kept a fatherly eye on the younger; many Liverpool geologists were members of both groups and there seems never to have been any antagonism or rivalry between the two bodies [328]. Interest in footprints in the junior body was proclaimed almost from the outset, since T. Shilston presented a general review paper on this topic to the Association as early as 1881 [319].

In 1883, Morton delivered to the elder Society a detailed map of the Storeton quarries (Fig.9) and gave a short explanatory address. The footprint bed was found to be about 4 ft. thick, consisting of sandstones separated by seams of marls. The prints were impressed into the marls; the moulds thus formed were rapidly filled by deposition of fine sand after an interval of drying out and the resultant footprint casts were consistently situated on the undersides of the sandy layers [126].

A series of ten slabs from Storeton quarries, all exhibiting *Chirotherium* footprints, was presented to the British Museum (Natural History) by "C. Westerndarp Esq." (reg. no. R.398 BMNH); no description of these has been published. The Museum had earlier (1882) purchased 6 slabs (reg. no. R.295 BMNH) from Sir Philip Grey Egerton's collection, all from Lymm and all exhibiting *Chirotherium* footprints, and was later to acquire several others by gift or purchase.

Finds of footprints at a new locality, Oxton Heath (where they had been located during excavations for a sewer), were reported to the Liverpool Geological Society by Charles Ricketts in 1886 [136]. Ricketts (1814—1900) was a Birkenhead doctor with a strong sparetime interest in geology, who twice served as President of the Society and was especially concerned with glacial geology. The Oxton footprints he described were plentiful, but they were disappointing in that no trackways were recognisable. Some birdlike prints were considered by Ricketts to be those of a rhynchocephalian reptile, *Rhynchosaurus*; this attribution is certainly incorrect, but Ricketts' specimens, now preserved in the Grosvenor Museum, Chester, have not yet been

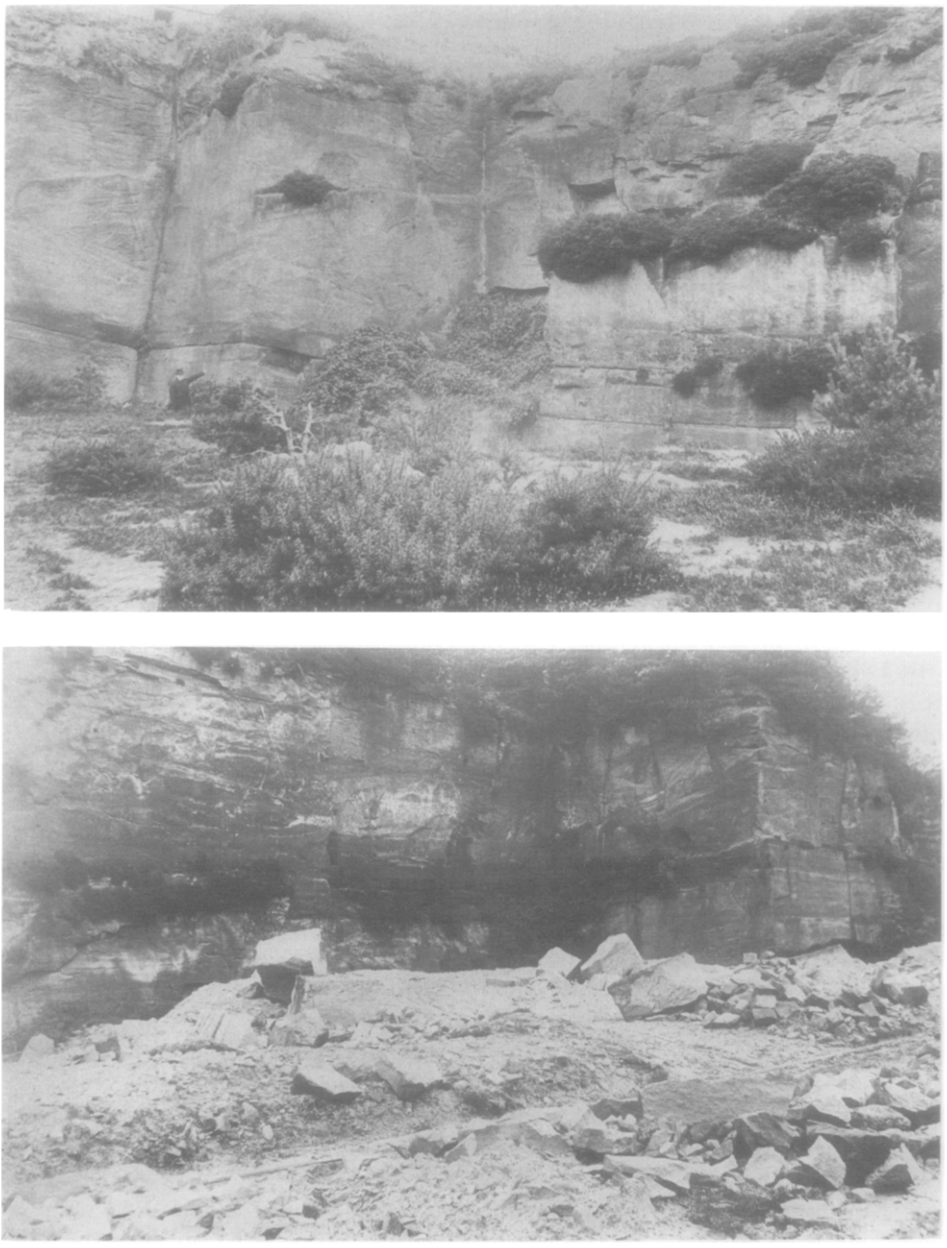

Fig.9. Storeton quarry, Cheshire, in 1881. The upper photograph shows George H. Morton pointing to the footprint bed in the exposure in the east side of the south quarry; in the lower, it is seen on the west side of the north quarry, being indicated by the line of vegetation. Photos: E. Newall, Beasley Collection, University of Liverpool.

fully illustrated or described, so their affinity remains to be determined.

In the same year a Dutch palaeontologist, T. C. Winkler, published a comprehensive review of existing knowledge of fossil vertebrate footprints, in which French summaries are given of most major British records up to that time [325].

Another general talk on footprints was presented to the Liverpool Association by James Hornell in September, 1889. Hornell (wrongly cited as Howell by Swinton [320]), pinned his flag firmly to the mast from the outset by entitling his discourse "The hand-footed Labyrinthodont". His ideas on the formation of the prints were strange indeed; he envisaged the unhappy labyrinthodonts, driven to "land on an inhospitable shore . . . taking, to their further misfortune, a line that led to the shores of the great salt lakes" along which "they wandered painfully and slowly, close to the edge of the water they dared not enter" [309, p.75].

On 20th June, 1890, footprints were found at "Mr. Leach's quarry", Runcorn, in the course of one of the Association's excursions [100]. One year later, a second edition of Morton's "Geology of the Country around Liverpool" was published, extensively revised and much enlarged. It contains lengthy descriptions and discussions of the fossil footprints, with the first photographs and drawings of the author's *Chirotherium storetonense* and with drawings of supposed *Rhynchosaurus* footprints and of impressions of various unnamed types. Some of the latter had been discovered by "the late Mr. Alfred Higginson about 50 years ago, in a quarry now long covered up, but which was then open, in Rathbone Street, corner of Washington Street, Liverpool" [127, p.110]. Higginson's discovery had originally been reported by Yates in 1840 [152], and it is quite likely that the footprints illustrated by Morton were collected by Higginson and Yates during their joint visit to the quarry.

In the previous year (1890), the Presidential Address to the Liverpool Geological Society had been delivered by Henry Charles Beasley, who was destined to become by far the most important figure in the history of British vertebrate ichnology (Fig.10). Despite his eminence in this field and despite his prolonged services for the Liverpool Society, no obituary of Beasley has ever been published in any scientific journal. The brief biography below is based on one in the "Liverpool Daily Post and Mercury" for 18th December, 1919 [66], with additions.

Beasley was born in 1836, probably in Liverpool. He was elected to the Liverpool Geological Society in January 1871, along with the famous author Charles Kingsley, and became one of its most active members; he served as Honorary Secretary for eleven years, as President for three terms of office, and as Editor for Volume 8 of the Society's Proceedings. His services to the Society were recognised by election to Honorary Membership in April 1916, and by the posthumous award of the Society's medal [144, 145]. He was also a member of the Liverpool Geological Association and the city's Biological Society, of which he also served as President. Although he had some

Fig.10. Henry C. Beasley (1836—1919), doyen of Cheshire vertebrate ichnologists. Photo: courtesy of Liverpool Geological Society.

interest in glacial geology and helped in the recording of striae and other phenomena in the Liverpool district, his main geological concern was always the Triassic. "The life of the British Trias" was the topic of his second Presidential Address, delivered on 8th October, 1889 [71]: footprints gain only scant mention in this, but his interest in them, and especially in the Storeton specimens, grew steadily thereafter. Largely through his efforts, the proprietor of the quarries, Mr. Charles Wells, was induced to seek out and preserve slabs exhibiting footprints; these were placed on one side, being propped up so that they could be inspected and so that the rain might clean them, after which they were preserved or disposed of according to their quality (Fig.11).

Beasley secured slabs from Storeton for the British Museum (Natural History), the collections of Liverpool University and several other institutions and himself assembled a fine representative collection. In addition to his work at Storeton, he searched all the quarries and outcrops within reasonable reach of Liverpool and visited, or corresponded with, all the

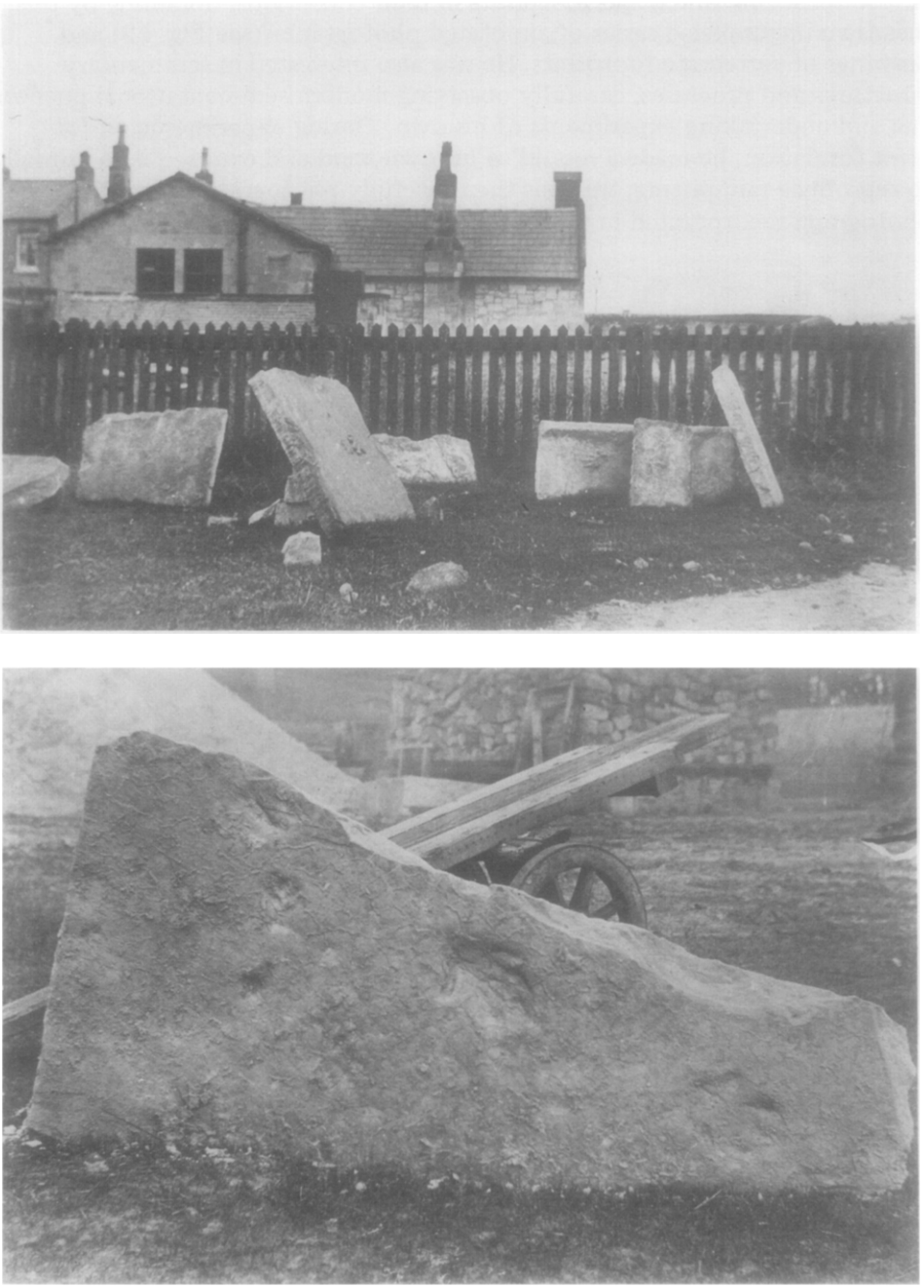

Fig.11. Footprint slabs propped up to weather at Storeton quarry, Cheshire in 1906. Photos: W. H. Rock, Beasley Collection, University of Liverpool.

British museums which had footprints in their collections, obtaining by this means an unparalleled series of annotated photographs (see Fig. 12) and drawings of vertebrate footprints. He was also interested in sedimentary structures and processes, carefully observing modern sedimentational phenomena and undertaking experiments of his own. During experiments on footprint formation, he made a mould of his own hand and exposed it to rainfall to reproduce rain-pitting; this was then carefully photographed and the photograph incorporated in his collection (Fig.13).

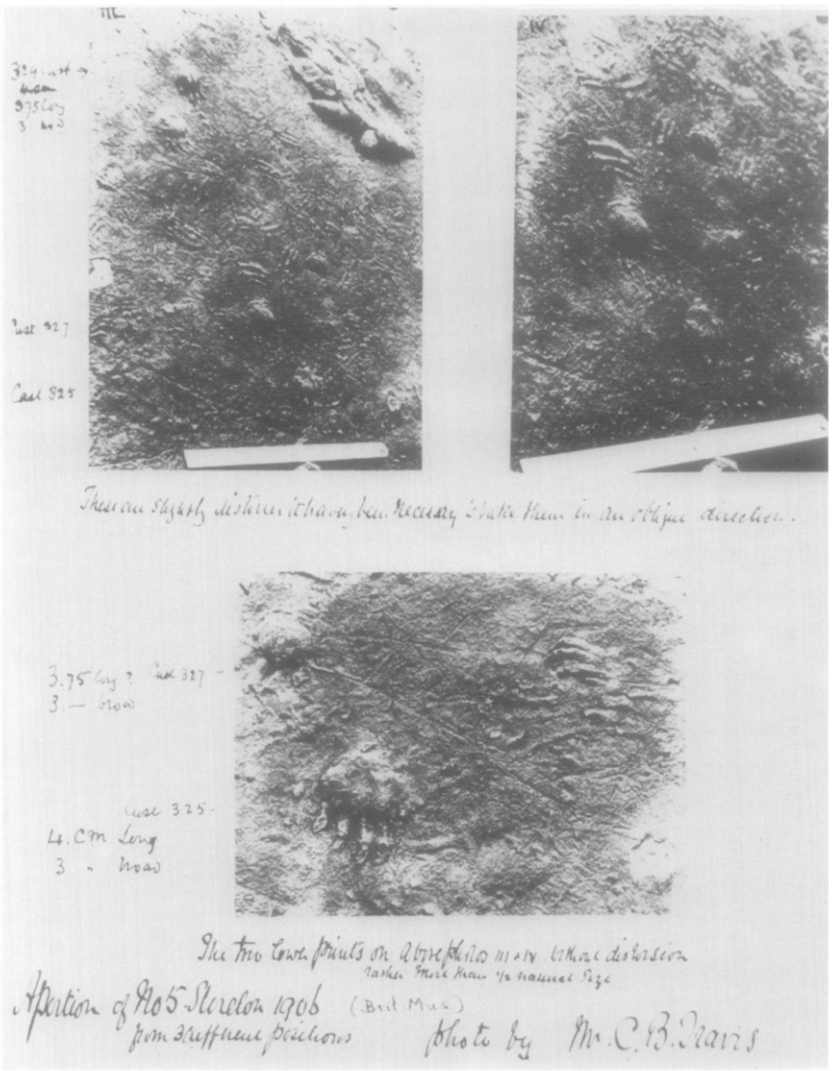

Fig.12. A photograph from the Beasley collection, mounted and annotated. (This illustrates the care with which Beasley assembled his records of Cheshire footprints.) Photo: Beasley Collection, University of Liverpool.

Beasley died on the 17th of December, 1919. After his death, his collection of photographs passed into the care of the Liverpool Geological Society; Dr. W. A. Cummins has described some of the Triassic sedimentary structures Beasley photographed [326, 327] and in 1971, I prepared and distributed a detailed catalogue of the collection, so that it might be more fully known and used [318]. Beasley's collection of footprint specimens was posthumously donated to the Liverpool Public Museum; unfortunately, much of it was lost as a consequence of war-time bombing in 1941. The portrait of

Fig.13. Imprint of Beasley's hand, with rainprints superimposed, prepared in 1909 during Beasley's experiments into the way in which vertebrate footprints came to be preserved. Photo: H. C. Beasley, Beasley Collection, University of Liverpool.

Beasley (Fig.10), the only one known to survive, was presented to the Liverpool Geological Society by his widow in March, 1920. His studies on footprints will be discussed in the chronological order of their presentation and publication.

In 1892, a paper on supposed footprints from Runcorn (Fig.14) was published by W. H. Miles in the Liverpool Geological Association's Proceedings [122]. Of much greater importance was the work of Osmund W. Jeffs, who presented to the Liverpool Geological Association in June, 1894, and on 11th August (more briefly) to the British Association at Oxford, the results of his study of a series of specimens from Storeton and Oxton Heath and of the slabs in Bootle Museum. He discussed the alternative names *Chirotherium*

Fig.14. Beetle Rock quarry, Runcorn, Cheshire. The footprint bed is the lowest light band, seen at right. Photo: C. A. Timmins, Beasley Collection, University of Liverpool.

and *Chirosaurus*: the latter had been adopted by the British Museum (Natural History) on the grounds that the creature forming the prints was certainly a reptile (this was in the days before the principle of priority in taxonomic nomenclature had been universally adopted) but though Jeffs' sentiment favoured the latter name, he adopted the earlier throughout and thus inadvertently acted in accordance with modern taxonomic procedure! In addition to listing *C. storetonense* and other unnamed large forms, Jeffs described and discussed a variety of types of smaller prints; some of them he attributed to *Rhynchosaurus*, some he considered to be chelonian, but the nature of the majority was not even speculated upon [110, 111].

The catalogue prepared by Black and Bisset shows that the indefatigable Dr. Thomas Boyle Grierson had by this time acquired a slab of footprints

"from near Birkenhead", almost certainly from Storeton, for his museum at Thornhill [7, p.20].

On 10th December, 1895, Beasley read to the Liverpool Geological Society what was perhaps his most important paper, thus making his entry into serious work on vertebrate ichnology. It is entitled "An attempt to classify the footprints in the New Red Sandstone of this district". Eight groups of footprints were distinguished, carefully described, and illustrated by outline sketches (Figs.15—17); each was designated by a letter (A—H). Group A contained the footprints of typical *Chirotherium* type (*C. herculis*, *C. storetonense*, etc.). Group B embraced small pentadactyl and palmate prints, ¾ to 2 in.; their discovery at a new locality (Moorhey, near Great Crosby) was noted.

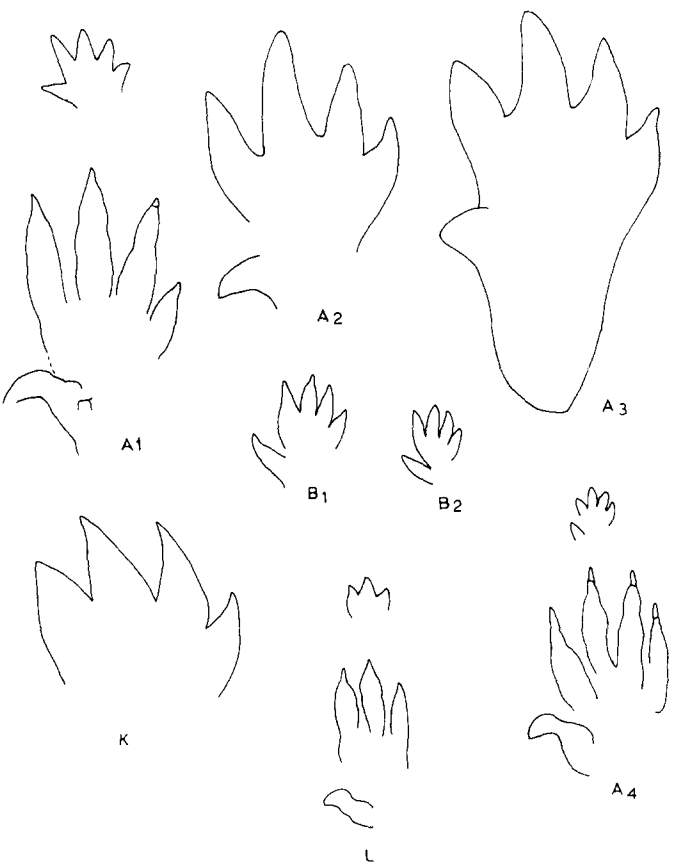

Fig.15. Chirotherioid prints from the English Midlands, as figured by Beasley (but here redrawn to constant scale). A1: *Chirotherium storetonensis* Morton; A2: from Lymm (*Chirotherium* cf. *storetonensis* of Kuhn, 1963); A3: *Isochirotherium herculis* (Egerton); A4: *Isochirotherium lomasi* (Baird); B1: Possibly *Chirotherium sickleri* Kaup; B2: form illustrated by John Cunningham (*Chirotherium* sp. of Kuhn, 1963). K: *Chelone? subrotundus* Morton (*Chirotherium* sp. of Kuhn, 1963). L: *Chirotherium beasleyi* Nopcsa non Peabody.

Group C contained similar but smaller (not more than ¾ inch long), rather stubby-toed pentadactyl prints. Group D included the types commonest of all at Storeton, with four slender hooked digits of progressively decreasing length clearly impressed, sometimes with the impression of an opposed, short fifth digit, sometimes without. These were the prints at this time attributed to *Rhynchosaurus*. Group E embraced somewhat similar prints of small size,

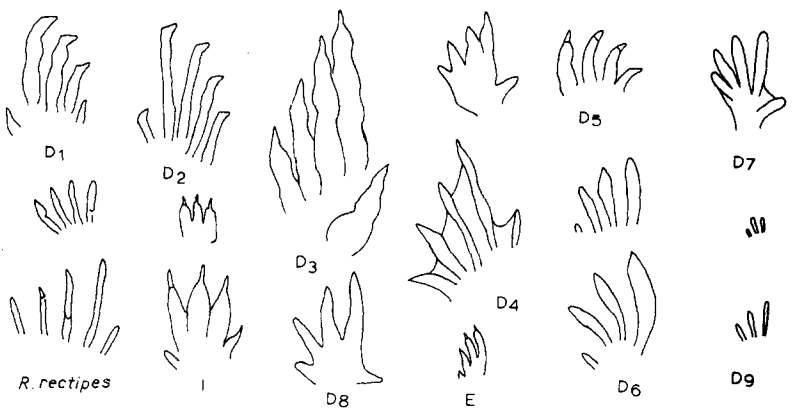

Fig.16. "Rhynchosauroid" prints from the English Midlands, as figured by Beasley and Maidwell. D1: *Rhynchosauroides articeps* Owen. D2: *Rhynchosauroides rectipes* Maidwell ex Beasley Ms. D3: unnamed type. D4: *Rhynchosauroides* sp. of Kuhn, 1963 (considered referable to *R. rectipes* by Haubold). D5: "perhaps *Procolophonichnium*", according to Kuhn, 1963; *Rhynchosauroides* sp. according to Haubold. D6: *Rhynchosauroides* sp. of Haubold. D7: *Rhynchosauroides beasleyi* Nopcsa. D8: *Rhynchosauroides membranipes* Maidwell. D9: *Rhynchosauroides minutipes* Maidwell. E: unnamed form. I: *Rhynchosaurus tumidus* Morton, doubtfully transferred to *Rotodactylus* by Haubold. Maidwell's (1914) figure of *Rhynchosauroides rectipes* is added for comparison.

the manus being poorly known but having at least four digits; the pes, with four slender, curving digits of progressively decreasing length, was only ½ in. long and yet twice the length of the manus. Group F comprised supposed chelonian impressions, with a well-marked ovoid palm impression and four short claws. Group G contained similar but larger impressions, the heel deeply imprinted but the claws poorly seen; only two are depicted in Beasley's diagram, though he specified up to four. These impressions were considered comparable with those from Dumfries-shire described by Huxley [47, 48]. Group H comprised three-toed prints with parallel toes, not truly tridactyl and probably representing imperfect, perhaps cursorial imprints of tetradactyl or pentadactyl feet; these included the types collected by the Liverpool Literary and Philosophical Society in 1846. Beasley noted that he had not encountered any impressions exhibiting webbing between digits. He emphasised his belief that a phase of desiccation was essential if the prints were to be preserved and noted the presence of suncracks in the footprint bed, but he felt that a returning tide would have destroyed the impressions and believed them to be preserved by wind-blown sand [73].

In the following year, Beasley presented some observations on a Storeton footprint to the Liverpool Biological Society, incorporating some comments made by Harry Govier Seeley. (Seeley, a vertebrate palaeontologist, was then simultaneously Professor of Geology and Mineralogy at King's College, London, and of Geography and Geology at Queens College in that city!) The footprint exhibited five digits, with the claws all turned outwards; Seeley thought this indicated a burrowing habit "and therefore an animal with long body, short legs and shoulder girdle of the Monotreme type, though the same conditions would be found in the Anomodont" [75, p.179]. Of these alternatives, Beasley strongly favoured the idea that this was an anomodont print, possibly of a reptile such as *Dicynodon* [75, p.180].

The year 1897 also saw the publication of a third edition of Morton's "Geology of Liverpool", Triassic footprints being discussed in the "Appendix". Morton concluded, on the basis of examination of specimens in Beasley's collection and in the University College, that six species were represented at Storeton — *Chelone*? *subrotundus* sp. nov. ("oval impressions, 1½ by 1 inch, with four toes and claws on the lateral side"), *Chirotherium storetonense* Morton; *Chirotherium minus* Kessler and Sickler*, a small form (pes 1½ to 2½ in. long) with narrow toes and 5th digit straight ("Has been supposed to be the young of the former species"); *Rhynchosaurus articeps* Owen ("Common. Length 1 to 1½ inches. Toes all curved, and nails distinct"); *R. minimus* sp. nov. ("Occasional. *Pes* about ½ an inch in length. Toes slender, tapering, and sometimes only 2 or 3 are preserved. The *manus* about 1/3 the length presenting faint impressions resembling those of the *pes*"); and *R. tumidus* sp. nov. ("Occasional. Length about 2/3 of an inch. Toes closely set, and impression of nails usually distinct on one or more of them"). He noted that a specimen of *Chirotherium storetonense* in the British Museum (Natural History) (R. 730 BMNH) showed "an apparent trace of the tail, between the footprints with impressions resembling scutes" and considered this to be evidence supporting dinosaur affinity [128].

In 1898, Beasley presented to the Liverpool Geological Society some notes on the collections in the Grosvenor Museum at Chester, the Victoria Institute at Worcester and the museums at Warwick and Shrewsbury. Among Jeffs' specimens in the Grosvenor Museum were examples of a further type of footprint, which Beasley designated Type I; this showed four toes, three of them of comparable length and exactly parallel, the fourth much shorter and slightly oblique to the others, all of them terminating in sharp claws. There was also a "*Cheirotherium herculis* from Lymm, presented by Miss Potts" (presumably the specimen described by Egerton and Taylor in 1839?). The Warwick collections were found to contain footprints from Lymm collected by "Richd. Corbett Esquire", but these were not considered of great interest [76].

In 1899, Seeley informed the Geological Society of London of the

* A junior synonym of *Chirotherium sickleri* Kaup; see Haubold [307, p.351].

discovery at Storeton of what he had now firmly decided was the footprint of a monotreme; his paper was published only in abstract, without further illustration [138]. Beasley never subsequently commented on this conclusion, but the fact that he excluded the footprint from treatment in his later reviews of Triassic footprints suggests he was unhappy about it. His alphabetical notation scheme contains no "J"; probably this letter was the one assigned to the supposed "monotreme". The original specimen of this problematic footprint is lost, but a cast is preserved in the British Museum (Natural History) (Specimen No. R.2923 BMNH), and is here illustrated (Fig.17).

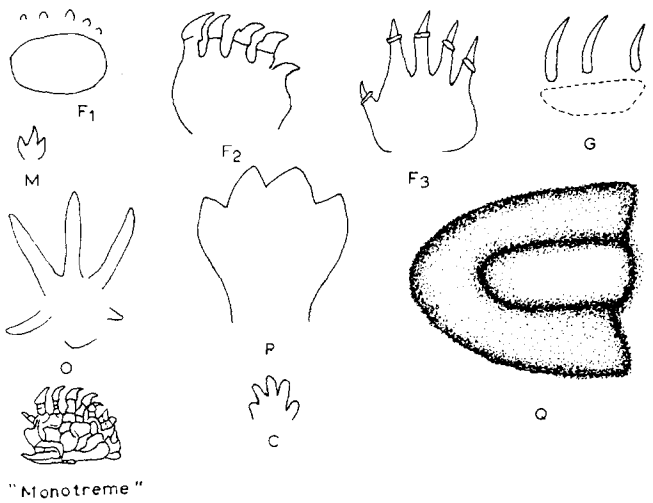

Fig.17. Miscellaneous prints from the English Midlands, as figured by Beasley but here redrawn to constant scale, F1—F3: "Chelonoid prints" of Beasley, considered by Haubold to be footprints of cynodonts. C, G, M, O: *Typopus* spp., according to Haubold. P, Q: unnamed types.

Beasley's own work on footprints continued at a steady pace. In 1901, he illustrated and described the holotype of *Chirotherium herculis*, Egerton's collection having been purchased by the British Museum and the type-specimen having been located for Beasley by Sir Arthur Smith Woodward [77]. The uncertainty regarding the locality from which it originally came was not, however, cleared up. Later in the same year, he gave, as its President, the Inaugural Address to the Liverpool Biological Society on "The fauna indicated in the Lower Keuper Sandstone of the neighbourhood of Liverpool", discussing the question of the identity of *Chirotherium* without coming to any firm conclusions [78]. In 1902, he described two further footprint types, K and L, from the Cheshire Trias. Footprint type K was moderately large, with four broad (ca. 5 in. in length) curving digits, the two outer being distinctly shorter than the two central ones, and with only the front part of the palm impressed. Type L was based on finds at Guys Cliff, Warwickshire; but the discovery of similar forms at Storeton was noted; it

was essentially of *Chirotherium* type, with a clearly opposed "thumb" but with only three, not four, "fingers, subparallel and bearing sharp claws" [79].

In November, 1902, the original lithographs prepared by John Cunningham for exhibition to the Geological Society of London were displayed to the Liverpool Geological Society; these had been searched out, mounted and annotated by Morton just before his death in 1900. Beasley's notes accompanying the exhibition were afterwards published [80].

When the British Association met in Southport in 1903, a committee was set up to investigate the Triassic fauna and flora of the British Isles; Joseph Lomas of the Liverpool Geological Society served as its Secretary till his premature death in 1908 (in a railway accident in Algeria whilst on British Association business). From the outset, Beasley associated himself with this work, the first of his series of "Reports on footprints from the Trias" being published alongside the first account of the Committee's activities [81]. In this, he reviewed the known footprint localities in England and in the supposed Triassic of Scotland. He then proceeded to deal with the cheirotherioid footprints; his original "A" group was divided into three units — A1 (*Chirotherium storetonense*); A2 (forms from Lymm with short fifth digit and digits 1—4 unusually acuminate in outline); A3 (*Chirotherium herculis*). Types "K" and "L" were illustrated and discussed, type "B" was subdivided, B1 containing the forms allocated by Morton (though not by Beasley!) to *Chirotherium minus*, and B2 the forms from Flaybrick Hill discovered by Cunningham. Beasley noted that he had not only found footprints superimposed on ripple marks, but had also encountered some large, imperfect prints with ripple marks superimposed on *them*, indicating that "a thin layer of water was still present over the mud, just sufficient to form the short ripples represented" [81, p.222]. A Storeton slab in the Museum of Owen's College, Manchester, with footprints of A1 type, was illustrated; this specimen is now in the Manchester Museum.

The Cheshire footprints were briefly mentioned by Thomas Sheppard in the introduction to his "Geological rambles in East Yorkshire", published in 1903 [139, p.2]. Storeton footprints were listed by E. T. Newton in a review of the Triassic fossils in the Museum of the Geological Survey at Jermyn Street, London, presented to the British Association committee at Cambridge, 1904 [52, p.285]. At this same meeting, Beasley presented his second "Report", dealing primarily with the supposed "Rhynchosauroid" and "Chelonoid" prints. Group D was subdivided into five units, D1 to D5 (see Fig.16), only types D1 and D2 being known from Cheshire. (No locality was quoted for type D5.) Group K was likewise subdivided; K1 was Morton's *Chelone? subrotundus*, K2 contained the forms first described in 1897, with strong sharp claws, firmly linked to the pad impressions. Beasley could not accept Morton's opinion that these latter should be also included in *Chelone? subrotundus*; he mentioned Seeley's idea that these were prints of an anomodont, but stressed the similarity to the footprints of the common mole (*Talpa europaea*) and suggested this was indicative of burrowing habits! In

addition, two "Incertae sedis" forms are listed; type I, which Morton had named *Rhynchosaurus tumidus*, and some very small tridactyl prints, known both from Westmorland and from Runcorn, which Beasley designated "Type M" [82]. A series of plaster casts of the thirteen types of footprints described in these two reports was subsequently presented by Lomas to the British Museum (Natural History) (reg. no. R.9248 BMNH).

What was effectively the third report, though not so entitled, was an account of fossils in the Warwick Museum presented to the British Association on Beasley's behalf at its meeting in South Africa; the only Cheshire prints mentioned are some imperfect chirotherioid (A2) prints from Lymm [262, p.164]. The fourth "Report", presented at York in 1906, included a description of a new chirotherioid type, A4, again recovered from Storeton, with pes comparable to A1 but somewhat slenderer and smaller; the manus, however, was very much smaller (one-seventh of the length of the pes), with only four broad, subparallel digits impressed. Type C was also described for the first time in the "Reports"; no speculations were made concerning its affinity. Discovery of footprints at a new Cheshire locality — a small quarry in the Waterstones, or perhaps the Upper Keuper, at Eddisbury — was noted [84].

On 13th November, 1906, Beasley once again addressed the Liverpool Geological Society from the Presidential chair; his talk was primarily on Storeton and its fossils. The raising of twenty new footprint slabs "each . . . well worth preserving" was reported. Footprints were now known to occur in three beds, separated a few feet from each other, at the northern end of the south quarry; quarry working had entirely ceased in the southern portion, which was now enclosed and partially used as gardens. The north quarry, on the west face of which the footprint bed was exposed, was closed. Whilst the beds appeared continuous throughout the Storeton workings, there was no proof of their contemporaneity with those at other Cheshire localities; whilst the position of the footprint bed at Runcorn appeared similar, the beds at Warrington and at Lymm appeared to occur higher in the succession.

The affinity of *Chirotherium* was again discussed. Beasley pointed out that this was a digitigrade animal, stressing its weight on its toes and the front of the palm; he favoured a dinosaur affinity, though he was unable to be more specific. He noted that, in some 400 square ft. of exposed surface, footprints of at least ten quite distinguishable types were recognisable, probably made by as many different types of animals during the limited period when the mud was sufficiently soft to take the impressions. Although the presence of water may have attracted them, an abundant fauna in the district was nonetheless suggested [83].

The fifth "Report", presented to the British Association at Leicester in 1907, was principally a discussion of the new finds at Storeton. Chirotherioid print type A4 was fully described and additional finds of type A1 were noted; in addition, a new "rhynchosauroid" type, D7, was described and

figured and specimens of a new "chelonoid" type, F3, comparable to F2 but with longer digits and more acuminate claws, were recorded [85]. At the same meeting the Secretary of the Committee, Joseph Lomas, described and illustrated prints of chirotherioid type A4 on a slab presented to Liverpool University [116]; his original drawing is here reproduced (Fig.18).

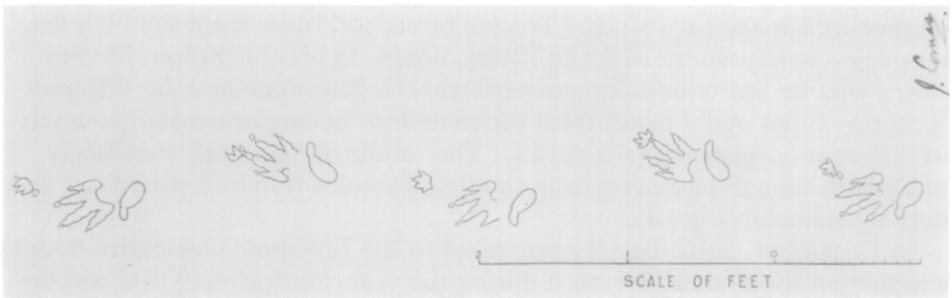

Fig.18. Chirotherioid prints; from an original figure by Joseph Lomas.

Beasley did not report at the 1908 meeting of the British Association, held in Dublin. However, A. R. Horwood of the Leicester Corporation Museum included Cheshire footprints in a bibliographic review of Triassic faunal and floral records from the English Midlands [108].

In 1909 the zoologist D. M. S. Watson presented to the Geological Society of London an account of reptilian tracks from the Trias of Runcorn, from which types A2 and E of Beasley were recorded and two new types, A8 and A9, mentioned. Watson suggested that the prints might be those of thecodonts such as *Ornithosuchus*. Unfortunately, his paper was published only in abstract [147, 148] and the character of these footprint types was thus left uncertain.

In the same year Beasley's sixth and last "Report" to the British Association was presented on his behalf at a meeting held far away in Winnipeg, Canada. A new type of footprint, rather spatulate in outline and with four broad, divergent toes was described and illustrated (type P: see Fig.17), but the report was essentially a summing-up of available data. He comments:

"The reasons for not giving generic and specific names to the various forms which were exposed in the earlier Reports still hold good. The identification of the animals who left the prints with any whose remains have been preserved is unfortunately not yet possible, and how far the different forms represent different species of animals is not absolutely certain. Under these circumstances, the specific naming of the prints would tend to error and confusion, which would be a worse result than the slight inconvenience incidental to the system of identification by letters and numbers." [86, p.152]

The geographical distribution of the prints attracted remark:

"It may be worth noting that the forms A1 to 4 are seldom, if ever, found at Runcorn, whilst they are common a few miles east and west, and that whilst A2 is common on

Lymm and Warrington slabs, it is rather rare at Storeton. The beds at each place are about the same age, although it seems difficult to correlate them with each other. There would seem to be little probability of a continuation of the same bed for any great distance if, as is now generally held to be the case, the beds represent the bottoms of isolated, somewhat temporary, pools and lagoons." [86, p.153]

The possible identity of the footprint-makers was again discussed, and the marked difference between the Triassic prints and those from the Permian, recently emphasised by Hickling [209], noted. In his conclusion, Beasley stated that he was undertaking experiments to determine how far different footprint types might result from the same foot being impressed into muds of different consistency [86, p.154]. The results of this work were never published, though photographs in the Beasley collection indicate that it was duly undertaken (Fig.13).

In December, 1910, Beasley presented to the Liverpool Geological Society a report on the finds at Storeton during the year. Footprint type G was discussed in detail on the basis of new material, a slab with a good cast having been presented by Beasley to the British Museum (Natural History) (reg. no. R4832 BMNH). The print was shown to be dissimilar to the Elgin footprints, with which it had been earlier compared, but Beasley still regarded it as chelonioid in character [87].

Early in the following year, another member, Frederic Thomas Maidwell (1872—1921), described to the Society some prints from Runcorn Hill. Maidwell was an instructor in handicrafts at Runcorn and a keen amateur geologist, who shared Beasley's special interest in footprints [67] and appears to have been his protégé. Unlike Beasley, Maidwell believed in giving generic and specific names to the prints he was describing and, most unexpectedly in view of Beasley's earlier comments, received the latter's support in this matter. All the D-type prints were firmly assigned to the ichnogenus *Rhynchosauroides*. The earlier name *R. articeps* Owen was assigned anew to type D1. A name formulated in manuscript by Beasley for some prints originally collected by Ricketts from Daresbury, in which the claws and digits were rectilinear and almost parallel, was published for the first time; this should presumably be cited as *Rhynchosauroides rectipes* Maidwell, 1911 ex Beasley Ms. No specific name was assigned to D2. A new type, displayed on a slab collected from the Runcorn quarries by Councillor William Handley and Mr. F. W. Hutton and housed in the Runcorn Free Library, was described under the name *R. membranipes*, webbing being considered to be present between the digits [117]. Webbed footprints are rare and webbing can be simulated by outbulging of mud from beneath the foot between spread toes; it would therefore be interesting to re-examine the type specimen, but unfortunately its present whereabouts — if the slab survives at all — is uncertain.

At a meeting of the Geologists' Association in London on Friday November 3rd, 1911, Mr. W. H. Bennett exhibited what the subsequent report termed "footprints of *Cheirotovium*" (sic) from Storeton [99]. The Cheshire foot-

prints were again briefly mentioned by A. R. Horwood, when he presented a paper on "The British Trias, a delta-formation" to the North Staffordshire Field Club in 1912 [310, p.128]. During that year the footprint bed at Storeton was exposed over an unusually large area, but Beasley found the results of the year's search disappointing and there is little of lasting interest in his report to the Liverpool Geological Society [88]. His final paper on fossil footprints was an account of a footprint from Runcorn Hill, read to the Society on 13th January, 1914; this was designated "Q" and is of obscure character, horseshoe-shaped and about 2—2½ cm long, not 2—2½ in. as Beasley erroneously stated [89]. (It may be noted that, on the back cover of the journal, this paper was quite irrelevantly titled "A Footprint from Weston", a fact which has occasioned confusion to later bibliographers.)

In April of the same year, Maidwell redescribed Black's prints from Weston; Black's type A were regarded as "Chelichnoid", his type C was considered to be *Rhynchosauroides rectipes*, his type D to be *R. membranipes* and a further type on the slabs, not apparently noted by Black, was given the new name *R. minutipes* and, for good measure, designated D9 of the Beasley system! In addition, descriptions of tracks of type D7 in the Manchester Museum and type I in the Grosvenor Museum, Chester, are given [118].

These two papers are the last manifestation of the Liverpool Geological Society's research interest in the Storeton footprints; however, its identification with this study had been strong enough for footprints to be chosen for the Society's emblem — a ripple-marked surface showing manus and pes impressions of *Chirotherium storetonense* Morton. This was first used as a design for the Society's medal and it is fitting that among the first four recipients (all of them posthumous) were three geologists who had worked on the Cheshire tracks — George Highfield Morton, Joseph Lomas and Henry C. Beasley.

At about this time, foreign geologists began to interest themselves in the Cheshire footprints. Othenio Abel in 1912 figured and briefly described a slab from Storeton in the collection of the British Museum (Natural History) (reg. no. R3483 BMNH), which showed a bipedal track of a *Chirotherium* [60, p.275, fig.201]. Much later, in 1935, he named it *?Chirotherium bipedale* [61, pp.55, 68, fig.35]. In 1923 Ferenc Nopcsa (also known as Franz von Nopcsa), a Hungarian geologist cum politician, published a major work on fossil reptiles in which footprints were also discussed incidentally. On the basis of the published figures, he elevated Beasley's type L to specific status as *Chirotherium beasleyi*, and somewhat confusingly allocated two new names to footprint type D7, which is cited both as *Rhynchosauroides beasleyi* and as *R. maidwelli*, the former name having priority [130]. In 1948 the American palaeontologist Frank Peabody, attempting an independent tribute to Beasley's work, proposed to name type A4 *Chirotherium beasleyi* [132]; but this was, of course, a junior homonym of Nopcsa's species. Accordingly another American palaeontologist, Donald Baird, proposed in

1954 the name *Chirotherium lomasi* for these footprints [70]; a photograph of the holotype, preserved in the museum of the Geology Department of Liverpool University, was published by Dr. J. C. Harper in 1956 [102].

Little of importance was done in England during this period. Wedd et al. in 1923 mentioned that quarries in the Basement Beds of the Keuper between Rathbone Street and St. James' Road in Liverpool had yielded *Chirotherium* [149, p.85]. Stella Harris, in her account of the growth of the geological collections in the Liverpool Public Museum, mentioned the purchase in 1908 of a slab from Storeton exhibiting chirotherioid and rhynchosauroid prints (this was illustrated in an accompanying plate) and the obtaining for the Museum in 1918 of the late H. C. Beasley's collections by Councillor C. S. Jones [103]. Unfortunately, the museum was burnt out, and most of its collections destroyed, during a German bombing raid in 1941; the footprint specimens that survive mostly no longer bear labels and have proved difficult to identify with any certainty.

S. W. Alty (1926) gave an account of rocks in a borehole near Wilmslow, Cheshire, recording footprints from a horizon at 660 ft. depth, which he then considered to be within the Keuper [62]; however, Taylor and Trotter (1963) showed that this in fact constituted the first record of footprints from the Upper Mottled Sandstone [141]. The footprint, once lodged in Stockport Museum and now lodged in Manchester Museum, was described by David B. Thompson in an unpublished thesis (1966); subsequently Warrington and Thompson (1971) noted that it was a *Chirotherium* print [146, p.70], but no description or illustration has yet appeared.

The Wilmslow occurrence was mentioned in a paper on "Footprints of the Past", contributed to the "North Western Naturalist" by R. K. Lawson later in 1926; Lawson also mentioned the occurrence of *Rhynchosaurus minimus* and *R. articeps* at Storeton and Runcorn, of *Chelone subrotundus* at Runcorn, and of unspecified footprints at Lymm, Weston and Tarporley [114]. In 1950, Neaverson briefly summarised the work of Beasley, Lomas and coworkers on fossil footprints in an account of the history of the Liverpool University geological collection [129].

Appropriately, when the centenary of the Liverpool Geological Society was celebrated in 1960, the distinguished vertebrate palaeontologist W. E. Swinton presented a paper on "The History of *Chirotherium*". His conclusion on these famous prints, so long a source of controversy, was that they were footprints of a group of diapsid reptiles, the pseudosuchians, which were capable of both bipedal and quadrupedal movement, one lineage becoming increasingly heavy and habitually quadrupedal. His conclusion was in agreement with the earlier work of Frank Peabody in the United States [317] Swinton's paper summarised much of the earlier English work on footprints, though a number of important references had escaped his attention and many were irrelevant to his topic [320]. At the time he wrote, fossil remains appropriate to the maker of the footprint tracks had not been found. In 1966, however, the first full description was published of a skeleton dis-

covered in Switzerland which fitted the bill very well — *Ticinosuchus ferox* Krebs [321]. Entertaining accounts of the earlier phases of the search for the elusive trackmaker were given by Willy Ley in 1951 [314] and Herbert Wendt in 1968 [323]; the story was brought almost up to date in a short note by Dr. Geoffrey Tresise of Liverpool Museum in 1969 [321] (It should be noted that the author's name was mis-spelled "Tresize").

Although no original research has been done in Britain on the Cheshire footprints for sixty years, they have continued to receive attention from continental geologists. In 1963, Otto Kuhn published a bibliography of papers on fossil tetrapod footprints; this is especially valuable as a guide to the complex continental literature on this topic, but it should be noted that several citations of English works are inaccurate and some of the works he listed are actually nonexistent. Kuhn reviewed the Cheshire records and made some attempts at attribution of Beasley's types to particular genera; A2 is cited as *Chirotherium* aff. *storetonense*, B1, B2 and K as *Chirotherium* sp., D4 and D6 as *Rhynchosauroides* sp., D5 as "perhaps *Procolophonichnium*" and M as "*Coelurosaurichnus?*" [313].

Hartmut Haubold, in 1969, published an assessment of the potential for stratigraphical correlation afforded by pseudosuchian footprints. He noted that the Cheshire footprints, though placed by British stratigraphers in the middle part of their "Keuper Sandstone", in fact included forms typical of the German Bunter! On this basis, he suggested a middle Anisian age for the Cheshire footprint-bearing strata. He considered *Chirotherium storetonense* to be a junior synonym of the type species of the genus *Chirotherium barthii* Kaup — sad news indeed for Cheshire geologists [104, p.838].

This opinion was reiterated in an important review of fossil amphibian and reptilian footprints published by Haubold in 1971, when a series of further sweeping taxonomic proposals were also made. Abel's species *C. bipedale* was considered to be a junior synonym of *C. herculis* Egerton; and the latter species, along with *C. lomasi* Baird, was transferred to the new ichnogenus *Isochirotherium.* Haubold distrusted the evidence for webbing between the digits of *Rhynchosauroides membranipes* and, in consequence, synonymised it with the senior *R. rectipes*; types D4 of Beasley and A9 of Watson were also treated as synonyms. Kuhn's suggestion that D5 might be perhaps a *Procolophonichnium* was not accepted, the form being retained as "*Rhynchosaurus* sp.". Type I of Beasley, which had been named *Rhynchosaurus tumidus* by Morton, was doubtfully reassigned to the genus *Rotodactylus.* The forms figured by Morton under the name *Chelone? subrotundus*, together with Beasley's chelonoid forms F1, F2 and F3, were considered to be the footprints, not of tortoises but of cynodonts, a group of carnivorous mammal-like reptiles. Beasley's form H was considered to correspond with *Plesiothornipos binneyi* Harkness, 1850; and his forms C, G, M and O were all assigned to the ichnogenus *Typopus* [306]; these assignations all seem to me to be highly questionable.

Unexpectedly, Haubold came to rather different conclusions in a major

review of Bunter footprints from Germany and elsewhere, which, after being a shorter time in press, was published later in the same year. The species *Chirotherium bipedale* and *Rhynchosauroides membranipes* were here treated as valid, though the generic attribution of the former was considered doubtful and the separation of the latter from *R. rectipes* still regarded as highly suspect. The greatest interest of this paper, however, lies in the fact that it clearly demonstrates the stratigraphical importance of fossil footprints in continental sediments [307].

In an account of the Keuper Sandstone Formation in the Cheshire Basin, David Thompson (1970) plotted the stratigraphic horizons of former discoveries of footprints in the Lower Keuper Sandstone and Waterstones near Storeton, Liverpool, Weston, Runcorn, Frodsham (Five Crosses quarry) and Daresbury as carefully as former accounts permitted. These footprints were related to a new lithostratigraphy. The frequent records from the Waterstones of the Lymm area [e.g. 134] could not, however, be related remotely to any horizon or quarry. New discoveries of footprints were recorded: a whole core surface with many prints of *Rhynchosauroides rectipes* Beasley in Maidwell in the Hayman's Farm borehole, Nether Alderley (now in the Geology Department, University of Manchester), a print from Pottbrook, Mottram St. Andrew, and a three-toed print discovered by Dr. G. Warrington near Wizard's Well, Alderley Edge [143].

Since that time D. Thompson (personal communication, 1970) has found many prints on Waterstones flagstones used for farm, garden or lane walls around Lymm; for example, *Rhynchosauroides* prints, "churning up rather thick mud", in the laneside at Booths Bank near High Leigh (NGR SJ 726848) and *Chirotherium* prints at Broomedge (SJ 98862) and in the wall around the public stocks at Warburton Cross (SJ 698896). Thompson and Mr. Rodney Ireland have found *Chirotherium* prints and a small three-toed print at Red Brow quarry, near Daresbury, some 250—300 ft. above the base of the Waterstones. In addition, Thompson informs me that a borehole at Eaton Waterworks yielded a footprint and that this is now on display to visitors.

An unusual recent event was the auctioning by Messrs. Sotheby, of London, in July 1971 of a very fine footprint cast, thought to be from Storeton, Cheshire, but of unknown history [140]. I was asked by members of the staff of both the British Museum (Natural History) and the Leicester Museum to advise them as to whether it should be purchased. On my recommendation, the specimen was purchased by Leicester Museum, for a price of £60 — a fair price, in view of its rarity and high quality (Fig.19).

The London "Daily Express" for 16th August, 1971, carried a short note recording the finding by Mr. Stanley Bull of a fossilised reptile's footprint in the garden of his house at Sandbach, Cheshire [68]. Mr. Bull courteously sent me some photographs and a careful drawing, together with a description and full measurements. The photographs and drawing were examined in consultation with my Nottingham colleague, Dr. J. A. D. Dickson. Our

conclusion was that the structures were unquestionably asymmetrical current ripples, probably of linguoid form and of shallow-water origin; certainly these were *not* vertebrate footprints.

In the report of an East Midlands Geological Society excursion, published in 1971, two footprint discoveries by the two excursion leaders, Geoffrey Warrington and David Thompson, were noted: the former had "discovered a tridactyl reptilian footprint in the Engine Vein Conglomerates near Castle Rock (SJ 8556 7880)" and the latter had obtained "footprints named *Rhynchosauroides*" from the "Wood Mine Conglomerate Formation in the Hayman's Farm Borehole (SJ 8566 7635)" [146, p.70]. No comments or illustrations were given on these discoveries.

Fig.19. *Chirotherium storetonensis* Morton: the specimen recently purchased by Leicester City Museum. Photo courtesy of Messrs. Sothebys.

The Storeton quarries ceased working during the First World War. Part of the quarry area is now a very pleasant public park; part is being filled in and progressively built over. Professor Wallace S. Pitcher, of the University of Liverpool, informed me that he was asked to judge whether the site was worthy of preservation as one of special scientific interest; his opinion, reasonably enough, was that, since the footprints occurred on the underside

of the beds and could only be obtained by quarrying, there were no logical grounds for scheduling the quarries for preservation.

In contrast, a restudy of the specimens from Cheshire preserved in public museums and institutions is urgently necessary. In view of our increasing knowledge of footprint affinities, such a study would add greatly to our knowledge of the life of the English Trias.

Warwickshire

In the "Proceedings" of the Geological Society of London for 1838, one may find recorded the donation to the Society's museum of a "Mass of New Red Sandstone with impressions of *Chirotherium* footsteps from Birkbeck, Warwickshire; presented by Roderick Impey Murchison, V.P.G.S. . . ." [259]. The first recognition of footprints in this county and in Cheshire thus took place almost simultaneously, but it was not until 1840 that Murchison, jointly with Hugh Strickland (the son-in-law of Sir William Jardine of "Ichnology of Annandale" fame), published the first account of Warwickshire footprints — not the same footprints, since the locality quoted in the published account was not Birkbeck but Shrewley Common! The prints were pentadactyl, without distinct claws and with all digits directed outwards, the manus markedly smaller than the pes. In this paper the Warwickshire sandstones were for the first time correlated with the German Keuper; thus, from the outset, the footprints were recognised to be Triassic [275]. The figured specimen was afterwards lodged in the Warwick Museum: the earlier specimen is not in the Geological Survey Museum, to which the bulk of the Geological Society's British collections were later transferred, and its whereabouts is now uncertain.

In 1842 Sir Richard Owen reported the discovery of skeletal remains of labyrinthodonts in sandstones of Triassic age at Warwick and Leamington and suggested that the *Chirotherium* footprints were made by these animals [276]. It was not until 1860, however, that *Chirotherium* prints were first reported from Warwickshire. They were discovered by the Rev. P. B. Brodie at Witley Green, near Preston Bagot, one mile from Henley-in-Arden; the specimen was lodged in Warwick Museum [264]. An account of Brodie's find also appeared in a German journal during the same year [265] and was mentioned, along with the Shrewley Common specimens, by Edward Hull in 1869, in his report on the Triassic rocks of the Midland counties [269, p.90].

In the autumn of 1845, the Scottish geologist Hugh Miller paid his first visit to England; his account of his visit, "First impressions of England and its people" (1847), contains this passage:

"On one large slab in the Warwick Museum, figured by Sir Roderick Murchison, we may see the footprints of some betailed batrachian, that went waddling along, greatly at its leisure, several hundred thousand years ago, like the sheep of the nursery rhyme, 'trailing its tail behind it'. There is a double track of footprints on the flag — those of the right and left feet: in the middle, between the two, lies the long groove formed by the tail — a groove continuous, but slightly zig-zagged, to indicate the waddle. The creature

halfway in its course lay down to rest, having apparently not much to do, and its abdomen formed a slight hollow in the sand beneath. In again rising to its feet, it sprawled a little; and the hinder part of the body, in getting into motion, fretted the portion of the surface that furnished the main fulcrum of the movement, into two wave-like curves. The marks on another slab of the same formation compose such a notice of the doings of one of the earlier chelonians as a provincial editor would set into type for his newspaper, were the reptile My Lord Somebody his patron. The chelonian journeyed adown a moist sandy slope, furrowed by ripple-markings, apparently to a watering-place. He travelled leisurely, as became a reptile of consequence, set down his full weight each step he took, and left a deep-marked track in double line behind him. And yet, were his nerves less strong, he *might* have bestirred himself; for the southern heavens were dark with tempest at the time, and a thunderous-like shower, scarce a mile away, threatened to wet him to the skin. On it came; and the large round drops, driven aslant by a gale from the south, struck into the sand like small shot, at an angle of sixty. How the traveller fared on the occasion has not transpired; but clear and palpable it is that he must have been a firm fellow, and that the heavy globular drops made a much less marked impression on the sand consolidated by his tread than when they fell elsewhere on the incoherent surface around him."
[274, p.190–191]

Thus vividly did Scotland's greatest geological writer describe the slabs he saw and evoke the conditions under which the impressions formed.

On July 10th, 1871, Brodie and an associate, J. W. Kirshaw, conducted a Geologists' Association party round various Warwickshire localities and, in the evening, to the Warwick Museum, where the footprint slabs were duly examined. The published report of this meeting notes that the museum collections contained, not only the Shrewley footprints (now considered to be those of *Rhynchosaurus*) but also *Chirotherium* footprints from the Upper Keuper of Preston Bagot and *Rhynchosaurus* footprints from Warwick (exact source not indicated, but probably Coten End quarry). On the following day, the party examined Brodie's own museum at Rowington Vicarage, where *Rhynchosaurus* footprints from Shrewley were again on display [266].

The report of a British Association Committee on the labyrinthodonts of the Coal Measures was presented at the Bradford meeting of the Association in 1874 by its Secretary, L. C. Miall. Owen's belief that *Chirotherium* prints were made by a labyrinthodont came under strong fire, as did his judgement on the systematic assignation of the bones from Warwick and Leamington [273].

The "Report of the Leicester Museum" for 1879 noted the acquisition of a "slab of rock showing footprints of extinct animals impressed upon its surface before the rock was hardened into stone"; since it had been presented by Brodie, this was presumably from Warwickshire [268]. Unfortunately the specimen has since disappeared and no records survive concerning it.

The Warwickshire footprints were mentioned in vague terms in an account of the Triassic rocks of the Birmingham area by W. J. Harrison in 1882 [267, p.242]. In 1890, when the Liverpool Geological Association visited Warwick, Beasley reported finding "labyrinthodont" and "Rynchosaurus" (sic) footprints in the Coten End quarry [261]. In Charles Lapworth's account of the geology of the Birmingham district, the footprints were again given cursory

mention [270]. However, no serious studies of them were made until 1905, when Beasley presented to the British Association the results of his studies of the specimens in Warwick Museum. The collection embraced some fifty slabs of sandstone exhibiting casts or impressions of footprints, about fifteen of them from the Upper Keuper Sandstone of Shrewley:

"one large one from Coten-end, Warwick, and several from both Upper and Lower Keuper in other localities in the Midlands, Beside these, there are others which have lost their labels, but of which it is possible to guess the locality." [262, p.162]

The specimens from Shrewley came from a quarry beside the canal; they were collected by the Rev. Brodie and other Warwick geologists, who had kept a regular watch on the quarry workings. (By 1905, the quarry was closed and already overgrown.) Most of the footprints proved of "Rhynchosauroid" character (Fig.16). The prints described by Murchison and Strickland had already been assigned by Beasley in 1904 to his type D4 [81]. The most common type on the other slabs was one with club-shaped digits, without obvious claws, distinguished as a new type (D6). A single slab exhibited footprints of type D1 and imperfect chirotherioid impressions were also noted [81]. Type D6 was again referred to by Beasley in his fourth "Report" in 1906 [84].

C. A. Matley, in a general account in 1912 of the Upper Keuper and associated strata in Warwickshire, mentions "Labyrinthodont and reptilian remains and footprints" at Rowington and Shrewley and "batrachian footprints" at Shrewley [272]. The Warwick footprints were also mentioned briefly in Horwood's address to the North Staffordshire Field Club later that year [310, p.128]. No subsequent Triassic discoveries in Warwickshire have been reported.

Shropshire

The finding of footprints in the Triassic of Shropshire was first announced at the Newcastle-on-Tyne meeting of the British Association, 1838, by Dr. O. Ward. The prints occurred on surfaces bearing ripple marks in a finely laminated, buff-coloured red sandstone "called 'Fee' "; Ward described them as differing

"from those of *Cheirotherium* in having only three toes, armed with long nails, directed forwards, not spreading out, and one hind toe on the same side as the longest fore toes, pointing backwards, and having a very long claw. No impression of the ball of the foot in this example; but in another there are three toes and a depression for the ball not unlike that of a dog." [223, p.75]

The footprints were discovered at Grinshill Hill (referred to by Ward as "Grimshill"), north of Shrewsbury.

Four years later, the finding of bones of a fossil reptile was reported by Sir Richard Owen from this same quarry; the name *Rhynchosaurus articeps* was applied to them and Owen accepted Ward's suggestion, conveyed to him by letter, that the footprints found in the quarry were those of this same reptile [222].

It was not until sixty years later, when the creation of the British Association's Triassic Committee stimulated Henry Beasley's researches into museum collections, that the Shropshire footprints attracted any further attention. In his second "Report", presented in 1904, Beasley commented on the difficulty of employing Ward's description to identify his prints, in the absence of either a drawing or a reference specimen; Beasley eventually concluded that they might be varieties of his "Rhynchosauroid" print type D1 [82, p.276] and it is with these that the name *Rhynchosaurus articeps* has come to be associated.

Beasley's account of the vertebrate footprints in Warwick Museum, presented to the British Association in 1905, mentioned two slabs from "Grinshill"; one had been presented by Sir Vincent Corbet, the other was of uncertain provenance. Both exhibited footprints of *Rhynchosaurus articeps*, which Beasley termed D1 [262].

In 1928, the Survey geologist H. Dewey noted "footprints of beasts", along with ripplemarks and worm burrows, in a pit in the Keuper Marl north of Oaken Park Farm (lat. 52° 38′17″, long. 2°14′24″) close to the county boundary near Albrighton (Whitehead et al. [237, p.146]). These have never been studied further and appear not to have been placed in the H.M. Geological Survey collections.

No subsequent studies of Shropshire Triassic footprints have been published. Specimens from Grinshill in the Geological Survey Museum, London, and in Shrewsbury Museum await redescription. Slabs with footprints can still be collected from this quarry (advance permission for visits must, however, be sought from the owner, Mr. Thurston) and indeed, Dr. John Stanley (Extramural Department, University of Keele) has some Grinshill specimens of which no account has yet been published. There is thus every promise that Shropshire vertebrate footprints will furnish new stratigraphic information in the future.

Leicestershire

The Triassic footprints of Leicestershire are very poorly known. They were first reported by J. Plant in 1856, who mentioned "Labyrinthodont" footprints from Leicester, found in the Upper Keuper in a railway cutting in Shoulder-of-Mutton Hill [202]. This record was included in A. R. Horwood's list of Triassic fossils from Leicestershire, presented to the 1907 British Association meeting in Leicester itself [198]; but when, in 1909, Horwood presented a preliminary account of a later footprint find from Leicestershire, he noted that the footprints discovered by Plant were "not forthcoming, so that some doubt must be entertained as to their nature" [199, p.162].

In 1876 A. Irving noted, incidentally in an account of the geology of the Nottingham area [210], that "Prof. Hull states that footprints of *Cheirotherium* have been observed at Castle Donnington . . ." (sic). No source for Irving's quotation has been located.

The specimen reported by Horwood in 1909 had been found thirty years

earlier, by Mr. J. Large, at about 8 ft. depth in excavations for a house in Derby Road, Kegworth. It occurred in a greenish sandstone, passing into "skerry", intercalated into red marls of the Lower Keuper. Horwood considered it definitely a *Chirotherium*, resembling *C. herculis* Egerton [199]. He mentioned the finds at Castle Donington and Kegworth in an address to the North Staffordshire Field Club in 1912 as constituting the most north-easterly English footprints discoveries [310, pp.128—129]. The discovery was earlier briefly cited in the "Victoria History of the County of Leicestershire" [201, p.10], where the footprints were stated to be those of labyrinthodonts — a harking back to a theory already long abandoned.

The Kegworth specimen was re-examined by the Liverpool geologist F. T. Maidwell in 1916; though Maidwell was able to state positively that it was *not* attributable to *C. herculis*, he was unable to decide on its true nature and labelled it merely as a "Chirotheroid print" [200]. The photographs presented herewith (Fig.20) are the first to be published of a specimen that still

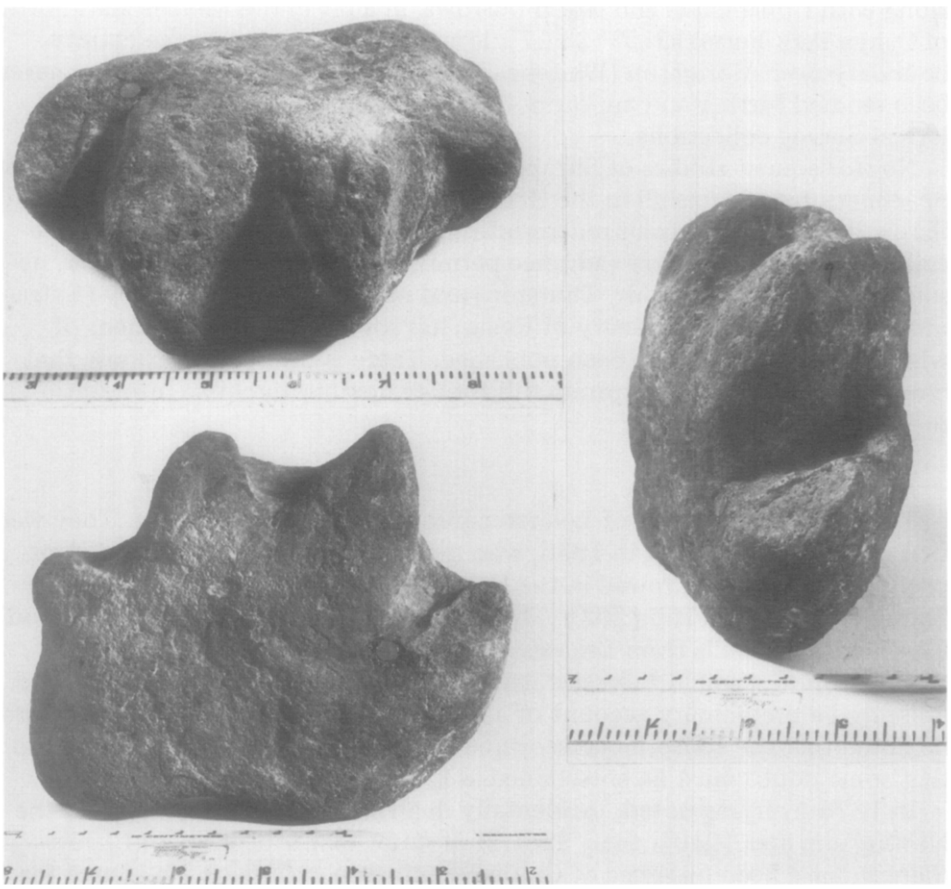

Fig.20. *Chirotherium* cf. *herculis* Egerton; from Kegworth, Leicestershire, in three views. Photos courtesy of Leicester City Museum.

remains significant, for no further discoveries of footprints from Leicestershire have been reported in the ensuing period.

Staffordshire

The catalogue of the British Museum (Natural History) records the purchase of two slabs from Staunton, 2½ miles from Burton-on-Trent, either in 1848 or 1858 (reg. nos. 21834 and 33156 BMNH). Whatever the date, these must be the earliest finds in the county, since it was not until 1860 that the Rev. W. Lister briefly informed the Oxford meeting of the British Association of his discovery of footprints of *Labyrinthodon* and *Rhynchosaurus* (1—2 in. long), *Chirotherium* (10 in. long) and of "another animal or animals with which I am not acquainted" in the New Red Sandstone at Brewood [230]. Three footprint-bearing slabs from Coven, near Brewood (reg. nos. 38803, 38805, and 40154 BMNH) were presented two years later to the British Museum (Natural History) by his clerical colleague the Rev. H. Housman; all exhibit footprints of *Rhynchosaurus* type.

The slab from Staunton, purchased by the British Museum (Natural History) in 1858 (reg. no. 21034 BMNH) is here illustrated for the first time (Fig.21). Many clear impressions of *Rhynchosaurus* type are well displayed.

Fig.21. Rhynchosauroid prints from the Triassic of Staunton, near Burton-on-Trent, Staffs. (Specimen no. 21834 BMNH). Photo courtesy of the British Museum (Natural History), London.

In 1863 the occurrence of footprints at Burton Bridge, Burton-on-Trent, was reported in two works — Mosley and Brown's "Natural History of Tutbury" [233] and the Rev. W. H. Coleman's geological chapter in White's "Gazeteer and Directory of the Counties of Leicester and Rutland" [158]. In the former work, they were attributed to *Chirotherium*; in the latter, they were described as "tracks of Labyrinthodon in ripple-marked sandstones". William Molyneux, in his history of Burton-on-Trent published in 1869, noted that *Chirotherium* footprints had been found in Ashby Road in that town [232]. These discoveries have never been adequately documented, though they served as stimulus for F. E. Lott's lecture on labyrinthodont footprints to the Burton-on-Trent Natural History Society as late as 1927 [231]

In 1892, when the Liverpool Geological Association visited Staffordshire, Henry Beasley was among the party and soon sniffed out some footprints. From quarries at Hollington, he reports "one small but perfect footprint and other traces . . . They may have belonged to a Rhynchosaurus, but more probably to a smaller lizard" [226, p.40]. In quarries east of the village of Alton, he noted "some very indistinct and uncertain traces of *Cheirotherium* footprints" [226].

In 1902, Dr. Arthur Smith Woodward, the vertebrate palaeontologist who was to inadvertently gain posthumous notoriety through his advocacy of "Piltdown Man", reported the discovery by Mr. Beeby Thompson of footprints in fissile Keuper Sandstones at Chillington. Chirotherioid and "Rhynchosauroid" (sic) prints were observed, together with what Woodward considered to be skin impressions [238]. A fuller treatment of this find, with better illustrations, followed in 1905 [239]; in the meantime Beasley had examined the rhynchosauroid prints and found them sufficiently distinctive to merit illustration as his type D3 [82, pp.277—278] (see also Fig.16).

In 1905 Beeby Thompson, in an account of Trias sections in south Staffordshire, mentioned his Chillington find [235, p.21] and noted the occurrence of *Chirotherium* footprints in the Keuper at Great Chatwell [235, p.22].

In the same year, Beasley described the footprints in Warwick Museum to the British Association; among them were three slabs from Brewood, one of them presented (and probably collected) by the Rev. F. Catt, another collected by that Warwickshire stalwart, the Rev. P. B. Brodie. The first slab was so crowded with prints that no single one could be easily studied; Beasley considered that they were probably attributable to type D3, to which type the better preserved prints on the second slab certainly belonged. The third slab exhibited a chirotherioid print "apparently of A2 form" [262].

The following year Beasley reported that, when the North Staffordshire Field Club and Liverpool Geological Society jointly visited Hollington, some footprints of a new type had been found in the Lower Keuper Sandstone in "Mr. J. Fielding's quarry, adjoining the workings in which the bones of Hyperodapedon were found" [84, pp.300—301, pl.2]. These imprints had strikingly divergent digits, three pointing forwards and two backwards; a

heel-pad impression was noted. They were designated a new type, O; the type specimen was lodged in Hanley Museum, Stoke-on-Trent. Unfortunately, Mr. A. R. Mountford, Director of Stoke-on-Trent City Museum, informs me on the basis of a recent search that the type specimen is no longer in the collections of the Museum and must be presumed lost.

The Brewood footprints gained brief mention in an H.M. Geological Survey district memoir in 1928 [237, p.133], but there have been no published reports of new Staffordshire discoveries in this century. However, a number of slabs exhibiting fossil footprints were collected from the quarries at Hollington during 1969 by Mr. A. W. Hart; an account of these footprints is to be published by Dr. Frank M. Taylor of the University of Nottingham.

Derbyshire

An incidental reference to the discovery by a Mr. Huish of "Labyrinthodont footsteps" on the further side of the River Trent, at Weston Cliff, in an account of Leicestershire geology by Edward Hull in 1860, constitutes the first published mention of Derbyshire Triassic footprints [160]. All other mentions of this find are similarly incidental. The Rev. W. H. Coleman's account of Leicestershire geology, published in 1863, briefly referred to "tracks of Labyrinthodon in ripple marked sandstones at . . . Weston-on-Trent" [158, p.100]; Montagu Browne, in his work on "The vertebrate animals of Leicestershire and Rutland", quoted Hull's note of the find [157, p.182]; and Fox-Strangways mentioned the find in his Geological Survey memoir on the Leicester area [159, p.115]. No description of these footprints has ever been published.

Footprints were collected by Henry Hurd Swinnerton, first Professor of Geology in the University of Nottingham, from a temporary exposure of the Keuper Waterstones at Dale Abbey, Stanton-by-Dale; the date of this discovery is uncertain. My description of them in 1967 constituted the first definite record of Derbyshire Triassic footprints. The footprints were those of a quadrupedal, plantigrade reptile with short digits, the pes being larger than the manus: this was clearly an efficient pedestrian, since the trackway was narrow and the stride proportionately quite long. The prints were attributed to the ichnogenus *Deuterotetrapous* as a new species, *D. plancus*; it was very tentatively postulated that they might have been formed by a quadrupedal thecodont reptile, perhaps related to *Aetosaurus* [212]. The type-specimen was discoloured and slightly damaged in a fire in the Geology Department, University of Nottingham, in March 1970; it is now lodged in the Natural History Museum, Wollaton Park, Nottingham. Two other specimens were collected by Swinnerton from Dale Abbey, but neither is of adequate quality for description.

Nottinghamshire

A. Irving, in his account of the geology of the Nottingham district in 1876, records that:

". . . I was so fortunate last summer as to pick up a block of stone bearing the unmistakable cast of the small forefoot of one of these creatures [*Chirotherium*]. The slab had fallen out of the cliff that overhangs the Midland Railway at Colwich (sic). The specimen is now in the museum of the High School." [210, p.73]

Irving's specimen came from the Keuper Waterstones at Colwick, in what is now the southeastern part of the urban sprawl of Nottingham; no description or figure of it has ever been published. The High School geological collection was recently kindly checked by Mr. David Manning on request; he reported, sadly, that the specimen could not be located.

In 1882, W. J. Harrison noted the occurrence of "footprints of *Labyrinthodon*" in ripple-marked sandstones, in a sequence of interbedded blue clays and sandstones in a brickyard south of Ollerton [206]. The beds must almost certainly have been in the Keuper Waterstones; however, this locality has not been pinpointed, nor have any other specimens been described from this vicinity.

A second Keuper Waterstones occurrence in the Nottingham city area was reported by Henry Hurd Swinnerton in 1910, in a temporary exposure whose whereabouts was specified only in such vague terms as "the Sherwood district" and "Mapperley Park" [217]. A photograph of the exposure was incorporated into an account of Swinnerton's lecture on "The Palmistry of the Rocks" to Nottingham Naturalists' Society in 1912, but this does not enable its geographic identification. Two types of footprints from this locality were illustrated and discussed in this lecture [218] but several other types present were not described.

Swinnerton's specimens were preserved in the collection of the Department of Geology, University of Nottingham and, in 1967, I undertook their description. Small prints with a very long second digit, *Microsauropus* aff. *acutipes* Moodie, were considered probably those of small, salamander-like amphibians. Prints equally small and partly obscured by tail drag, in which the digits were of fairly constant length and angle of divarication, were assigned to *Varanopus* aff. *curvidactylus* Moodie and considered to be probably also footprints of small amphibians. Broadly spreading hind foot impressions were attributed to the ichnospecies *Brachychirotherium cobergense* Aumann and considered to be footprints of thecodont reptiles. A large tridactyl impression was considered to be the footprint of a coelurosaur and therefore attributed to *Coelurosaurichnus* sp. Most interesting of all were some tridactyl impressions with clear indication of webbing between the digits; these were made the basis for a new ichnogenus and species, *Swinnertonichnus mapperleyensis*, and considered also to be probably coelurosaur footprints. A varied reptilian/amphibian fauna was thus indicated for Triassic Nottinghamshire, when conditions were visualized as being those of the margins of a lagoon in a semi-desert countryside [212].

Rather surprisingly, none of the footprints found at that time appeared referable to either of the two types described by Swinnerton in 1910. Later, however, a footprint of Swinnerton's type A came to light in the Nottingham

collections and was redescribed by me during 1970 under the new name *?Otozoum swinnertoni*; this was a much more massive imprint of a bipedal saurischian dinosaur, probably of a prosauropod, a member of the lineage leading to the huge sauropod dinosaurs of the Jurassic [213]. No examples of Swinnerton's second type have yet been located.

A fire swept the top floor of the Geology Building of the University of Nottingham in late March 1970. The Nottingham footprints, which had been on display for the University Open Day, were all discoloured and the holotypes of *Swinnertonichnus mapperleyensis* and *?Otozoum swinnertoni* were damaged through flaking of their surfaces in the intense heat; however, since they narrowly escaped complete destruction, matters could have been much worse! They are now lodged in the collections of the Natural History Museum, Wollaton Park, Nottingham.

In 1969, in a paper emphasising the potential afforded by the footprints of pseudosuchian reptiles in stratigraphical correlation, Hartmut Haubold noted that the Nottinghamshire assemblage I had described included the earliest footprints of quadrupedal thecodonts (aetosaurs) [104, p.840]. The Nottinghamshire footprints were dealt with more fully in Haubold's massive review of herpetological ichnology (1971), several being figured. Haubold's illustration and description of *Swinnertonichnus* omitted mention of the webbing, for he was then unwilling to accept the evidence for it [306], but we have since discussed the matter in correspondence and Haubold is now prepared to admit that his original judgement was erroneous. In a subsequent paper, Haubold (1972), referring to the Nottinghamshire occurrence of *Coelurosaurichnus*, noted that this was the stratigraphically earliest record of footprints of that type [207, p.99].

Worcestershire

Whilst, as has been seen, fossil footprints are not uncommon in the English Keuper, there were for long no finds from the Triassic beds termed in England the "Bunter" (though now known *not* to be of the same age as the German Bunter). The reason for this is, quite simply, the nature of the sediment. The Keuper consists in many areas of compact sandstones with occasional clay horizons, the footprints being impressed into the clay and cast by the sandstone. The sandstones themselves are suitable for working as building stones. The "Bunter" sediments are, in contrast, of much less coherent lithology and unsuitable for quarrying, so that, on the one hand, preservation of footprint casts is less probable and, on the other hand, the casts are less likely to be discovered, since natural weathering in exposures or road-cuts is unlikely to produce blocks of suitable size to display footprints.

Footprints from the English Bunter were first reported by Harkness in 1850, but this stratigraphic assignation is in the highest degree suspect (see discussion, p.298). It was not until around 1968 that Emeritus Professor Leonard J. Wills, formerly of the University of Birmingham and an outstanding figure in the history of British Permo-Triassic stratigraphy, recog-

nised footprints in undoubted Bunter sediments. He found them on the surfaces of weathered sections of an 18 in. diameter core sunk by the East Worcestershire Waterworks Co. at Bellington; the core traversed the Bunter Pebble Beds and Upper Mottled Sandstone down into the Permian Dune Sandstones. Footprints were present in both Triassic sequences; they were in general very shallowly impressed and proved extremely difficult to study, even under the most favourable conditions of illumination.

A report on these footprints was presented by Prof. Wills and me to the International Symposium on Trace Fossils at Liverpool early in 1970 and published later the same year. Footprints of eight different types were recognised: *?Aetosauripus* sp., *Coelurosaurichnus* cf. *ziegelangernensis* Kuhn, *Coelurosaurichnus* spp. (A and B), *Rhynchosauroides* cf. *pisanus* (Fucini), *Rhynchosauroides* sp., *Hamatopus* sp. and *?Procolophonichnus* sp. As may be perceived from this list, the tracks are not of adequate quality for close identification but indicate a varied reptilian fauna — pseudosuchians, coelurosaurs, rhynchocephalians and/or early lizards, and possibly cotylosaurs [284]. All the specimens described have been lodged in the Museum of the Geology Department, University of Birmingham, and a cast of the slab displaying the *?Aetosauripus* track was presented to the Institute of Geological Sciences.

The footprints gained incidental mention in Prof. Wills' account, published alongside his joint paper with me, of the stratigraphy of the Bellington borehole [282] and were referred to in his general review of the Midlands Triassic succession, published later the same year [283]. Further tracks have since been recognised by Prof. Wills in other sections of the Bellington cores, but these are unfortunately not of suitable quality for detailed study.

Vertebrate tracks have been reported from the Keuper beds of Worcestershire at a very much earlier date, the discovery of *Chirotherium* imprints in a quarry near Barrow Church, Malvern, having been noted in a Geologists' Association excursion report in 1874 [281]. These tracks are preserved in Gloucester Museum, but have never been described; nor has there been any subsequent report of vertebrate footprints in the Worcestershire Keuper.

Devonian "footprints"

In 1835, a work entitled "Observations on certain curious indentations in the Old Red Sandstone of Worcestershire and Herefordshire, considered as the tracks of antediluvian animals; and the objections to such an hypothesis refuted", was published by Jabez Allies [192]. The title summarises the main section of the work fairly exactly for, though articles on a series of subsidiary topics (from black rats to the antiquity of the signs of the Zodiac) form the bulk of the text, the book is nonetheless concerned with the description and interpretation of markings in the Old Red Sandstone of Whelpey and Sapey Brooks in those counties. Allies discussed the impressions, person-

ally or by correspondence, with a number of geologists. Among them was William Buckland who in turn discussed the markings with Murchison; their conclusion was that "the cavities are void spaces from which concretions of marlstone or other matter have been washed out by the action of the brook" [192, p.43]. Though Allies staunchly refused to accept this judgement, his eminent correspondents have come to be adjudged correct; quite certainly, the structures he figured are *not* footprints.

Allies also mentioned the discovery by Mr. John Amphlett, of Dunclent, near Kidderminster, of "some remarkable impressions in Dick Brook, in the parish of Aka, or Rock", Worcestershire. After discussing their legendary origin as footprints of the mare and colt which transported the stone for Rock Church, he continued:

> "That the marks were scattered along the stream for some distance, and situated a mile and a quarter above Rogers' Mill, between Knott's and the Worsley Estates, a little higher up than the spot where a road crosses the brook about two miles south east from Rock Church." [192, pp.127—128]

Allies visited the locality with a friend on 22nd June 1835 and duly found what he called "frogular impressions" (his name for "*genuine foot marks*"), though he noted that they were in general worn and covered with moss. His illustration shows circular impressions with a raised central region, indeed rather like horse hoofmarks but quite *unlike* the footprints of any animal likely to have been in existence in the Devonian.

Dr. Isles Strachan, of Birmingham University, kindly pinpointed for me three places (all in National grid square SO7571) where a road crossed Dick Brook or its tributaries. The most northerly was in the narrow outcrop of the Etruria Marl with sandstones (Carboniferous) but the other two both within the Old Red Sandstone (Dittonian). Stratigraphically, then, Allies appears to have been accurate, but, despite his expressed confidence, the impressions he reported cannot be considered to be vertebrate footprints; nor indeed have vertebrate tracks yet come to light in any British Devonian sediments.

Carboniferous footprints

Cheshire

Some years before 1856 (the exact date is uncertain), Mr. James Rhodes noted a series of five large impressions on a bedding plane surface in a quarry at Tintwistle, near Mottram-en-Longdendale. The beds in which they occurred were in the lowest part of the Millstone Grit, not far above the base. The impressions were all large, around 17 in. in length at the top of the impression, 13 in. at the base: they were set 2 ft. 10½ in. apart.

They were studied by E. W. Binney, who believed them to be footprints of large size, impressed into wet sand; he believed two feet had been successively set into each impression, the displacement of the semifluid sediment occasioned by the implantation of the second foot having partially obliterated

the print of the first. Impressed by their size and noting an analogy with the Corncockle Muir footprints, he proposed the name *Chelichnus ingens* for them [90, 91]. No illustration was published, but a drawing of the prints was deposited in the Geological Society library; unfortunately, it has since been lost. The find was briefly mentioned by Symonds in 1857 [37] and *Chelichnus ingens* was cited in the compilative works by Kuhn [313] and Haubold [306], but its nature has remained a matter for speculation.

The principal trackway from Tintwistle was quarried out and is now on display in Manchester Museum. The great size of the block now exhibited makes it clear that its extraction must have been a difficult and expensive operation; unfortunately, no records survive concerning the date at which, or the method by which, this was done. It is illustrated here for the first time (Fig.22); my reexamination entirely supports Binney's conclusions on the

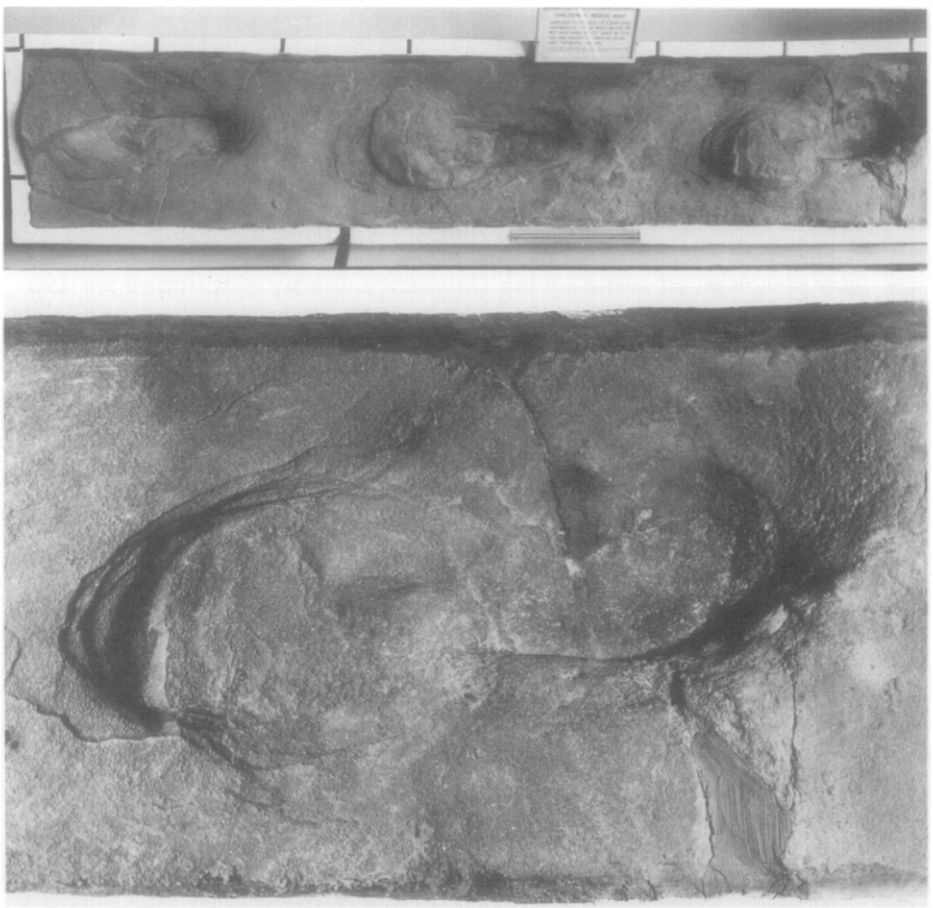

Fig.22. *Chelichnus ingens* Binney, from the Carboniferous of Tintwistle, Cheshire. Photo courtesy of the Manchester Museum. Top: the entire slab; bottom: close-up of imprint at extreme right. The whole slab measures 8 ft. 4½ in. x 1 ft. 4½ in. (255 x 42 cm).

manner of imprinting of the footprints and the size of the prints fully merits the name he proposed, though their quality scarcely justifies his naming of them! For this reason, no redescription can usefully be attempted.

Fig. 23. *Chelichnus ingens* Binney. Topotype. Photo courtesy of the Science Museum, Salford. The slab measures approx. 5 ft. x 4 ft. (150 x 120 cm).

In the course of recent correspondence concerning the whereabouts of footprint specimens, I was informed by Mr. R. J. Bradbury, Keeper of the Science Museum, Salford, that a block of Millstone Grit from Tintwistle containing impressions (its label damaged and incomplete) was housed in that museum. It exhibits a complete "footprint" of *C. ingens* at centre, with the "heel" of a second print slightly in front and another at upper right; other impressions appear merely to represent weathered-out concretions (Fig.23). The existence of this second specimen raises many questions; clearly it is at least a topotype, but was it or was it not a part of the same trail, quarried out at the same time?

Though the nature of the animal forming tracks cannot be determined accurately, it should be noted that amphibians (embolomeres) large enough to have made such tracks are known from skeletal remains in the Carboniferous. No other tracks have yet been recorded from the Carboniferous of Cheshire.

Northumberland

Footprints were first discovered in the "Lower Sandstones of the Carboniferous Limestone Formation" at Berraker Shields quarry, Deanhead, near Otterburn, North Tyne, by the quarry owner, Mr. R. B. Sanderson. Further specimens were subsequently obtained by Mr. G. A. Lebour of H.M. Geological Survey and Thomas Pallister Barkas; a description of them was published in the latter's "Illustrated Guide to the Fish, Amphibian, Reptilian and supposed Mammalian remains of the Northumberland Carboniferous strata" in 1873. The footprints occurred in a sandstone between the Long Syke Limestone below and the Potts Durtree Limestone:

"The Berraker Shields Sandstone Quarry, which is very small, not being more than 30 ft. long, 12 ft. wide, and 2 ft. deep, is, for the most part, worked for the purpose of obtaining flat sandstones with which to build what are locally designated "stells" or roofless circular buildings, about 20 ft. diameter, with walls about 4 ft. high. They are used for the purpose of sheltering sheep during the storms that occasionally prevail in that lofty district. The flat sandstones, because of their flatness, admirably answer the purpose of building rough walls without the necessity of using lime in order to strengthen the buildings that are erected upon the open moors, and the walls themselves afford an excellent field for ichnological research, as the stones, after having been exposed a few months to the weather, have washed from their surfaces the clay on which they were originally embedded, and the footprints, or rather the casts of the footprints, stand upon the stones in bold relief." [203, p.52]

Two types of footprints were represented: tracks of a quadrupedal, plantigrade animal of small size and broad trackway (see Fig.24a), which was given the name *Platytherium psammobates* gen. et sp. nov., and of a tridactyl, plantigrade quadruped of slightly larger size again with a broad trackway, which was named *Tridactylosaurus sandersoni* gen. et sp. nov. (Fig.24b). Barkas considered it "not improbable" that the former tracks were those of "a small, broad, four-legged mammal" [203, p.54]; he made no comparable comment upon the latter. The slabs into which they were impressed were ripple-marked

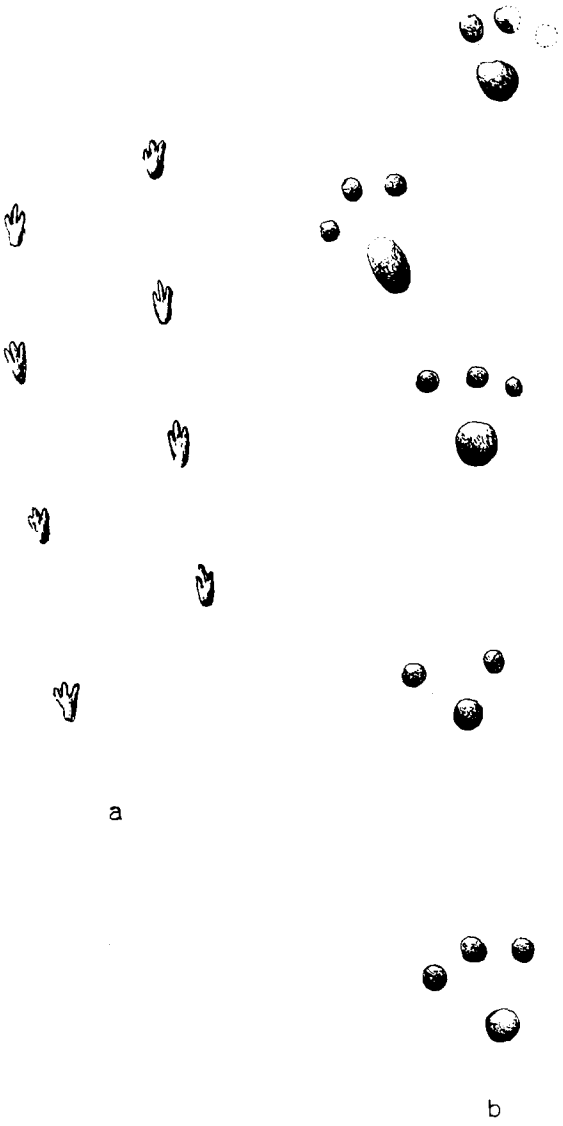

Fig. 24. Carboniferous footprints from Northumberland. a. *Platytherium psammobates* Barkas. b. *Tridactylosaurus sandersoni* Barkas.

and bore worm tracks and crustacean markings, together with "a curious and distinct cast of an unknown ammonite-like crustacean, with long tentacles" [203].

A brief account presented by Barkas to the British Association meeting at Newcastle-on-Tyne in 1889 suggests that he had made further discoveries of tracks in what he now was able to term the Lower Calciferous Sandstones [204], but no detailed descriptions were forthcoming; apart from their

inclusion into Haubold's comprehensive review of amphibian and reptilian footprints in 1971, where they figure as footprints of uncertain systematic character [306, p.95], the tracks described by Barkas have received no subsequent attention, nor have any others been reported from Northumberland.

Shropshire

Vertebrate footprints were first discovered in the Forest of Wyre Coalfield, at localities in the area between Bridgnorth, Shropshire, and Bewdley, Worcestershire, by the late Dr. Frank Raw of Birmingham University [224, p.65]. The richest finds were made in exposures of the Keele Beds in the disused and partly flooded Butts quarry at Alveley, Shropshire. According to L. J. Wills, in his obituary of Raw, they were first discovered during a mapping class and were collected after Raw had induced the Kidderminster Fire Brigade to pump out the quarry [225]. Certainly a fine collection of footprint-bearing slabs was extracted and taken back to Birmingham University; Raw intended to publish a description of them, but never actually did so.

Consequently, when I embarked upon a redescription of footprints in the collections of Birmingham University Geology Department (see p.340), these footprints demanded especial attention. Through the courtesy of Dr. Isles Strachan, a number of slabs were obtained on loan for study at the University of Nottingham in 1969; unfortunately, while this work was in progress, a fire destroyed the upper floors of the Geology building (where they were then housed) and my research received a serious setback. I therefore invited Dr. Haubold of Halle, Germany, to join me in completing this work. We originally envisaged studying all the Birmingham collections, but my immigration to Canada in 1972 necessitated abandonment of this plan.

By this time, however, the great interest of the Alveley assemblage had already become clear to us. Six ichnospecies were recognised. The most abundant track, that of a small amphibian, was identical with a form already known from the Lower Permian (upper Autunian) of Germany, *Anthichnium salamandroides* (Geinetz). All the other tracks identified, however, were new. They included amphibian tracks of similar form but markedly larger size and dissimilar stride angle, which we named *Anthichnium major*. Tracks of another small and slow-moving amphibian, placed into a second new ichnospecies (*Batrachichnus alveleyensis*), and of a larger labyrinthodont, given the name of *Limnopus rawi*, were also present. In addition, tracks of a carnivorous quadrupedal reptile, almost certainly a sphenacodont, were recognised and named *Dimetropus salopensis*, together with those of a large, blunt-clawed reptile with a narrow trackway, surely a herbivore and probably an edaphosaur (*Ichniotherium willsi*).

The presence of so many new types, and the paucity of types identifiable with known species, provided strong indication that this ichnofauna predates the well-known ones from the German Lower Permian. Since Stephanian assemblages are, in contrast, relatively little known — and, in particular, because *Ichniotherium willsi* appeared a probable precursor of the Autunian

form *I. cottae* — we assigned a Stephanian age (probably late Stephanian) to this assemblage [220, 221].

There have been no other records of footprints from the Shropshire Carboniferous.

Warwickshire

The only reference to vertebrate footprints in this county is a mention by L. J. Wills, Frank Raw and F. W. Shotton (1935), in their report of a Geologists' Association excursion to the Birmingham district, of "a few poor footprints", along with suncracks and raindrop impressions, in the exposure of the Ashow Group (Upper Carboniferous) at Whitemoor Brick Works, near Kenilworth [279, p.398].

Permian footprints

Cumberland

In a paper presented to the Geological Society of London on May 28th, 1884, George Varty Smith, a Penrith solicitor who was a keen amateur geologist [155], summarised the early history of vertebrate footprint study in the county:

"Hitherto not many footprints have been met with within the Penrith Sandstone. Impressions of the same nature as those found at Dumfries have been previously met with at Brownrigg in Plumpton, about five miles north-west of Penrith; and the late Mr. Binney and Prof. Harkness have noted similar impressions in the flaggy beds near Penrith, but they were not so distinct as those at Brownrigg." [156, p.479]

So far as has been determined, there are no published records of these earliest finds of English Permian footprints.

Smith's own discoveries were made in a quarry about 3½ miles east of Penrith, north of the Penrith—Alston road. Casts of the footprints were exhibited at the meeting and subsequently presented to the Society's Museum (their present whereabouts is unknown); in consequence, no drawings were provided and Smith's descriptions are too vague to be helpful. All appeared to be tracks of quadrupeds, at least four different animals being apparently represented. Smith also reported a find of footprints at Whinfell Wood, on a hilltop 3 miles south-east of Penrith; these were less distinct and he neither cast nor described them [156].

In his review of British Permian footprints in 1909, George Hickling described and illustrated Smith's specimens. He noted that they included "Chelichnoid" forms, with manus and pes of more or less equal size: in some instances, the impression of the pes was almost exactly superposed on that of the manus. The sole was poorly impressed in all instances. On this basis, a comparison with *Chelichnus ambiguus* Jardine appeared appropriate. Other prints were of "Lacertoid" form — digitigrade, all digits curving; yet others were again possibly "Chelichnoid" (though more indefinite in form) and

were considered perhaps comparable to tracks Hickling had described from the Permian of Nottinghamshire [209].

Smith's finds received incidental mention in papers on Cumberland stratigraphy by J. G. Goodchild in 1891 and 1893 [153, 154] and in R. L. Sherlock's review of the Permo-Triassic of northern England in 1926 [34]. The specimens are now lodged in the Sedgwick Museum, Univeristy of Cambridge.

Three slabs exhibiting tetrapod tracks comparable to those from Dumfriesshire were discovered in the Lazonby Sandstone at Lazonby Fell quarry in 1937. The quarriers, Messrs. William Graves, presented two of the slabs to Carlisle Museum: the whereabouts of the third is unknown. A description of the two slabs was not published until 1967, when Justin Delair showed that one of the tracks was attributable to *Chelichnus* sp., the second (which he figured) being apparently of a new type, too poorly preserved for description [12].

Nottinghamshire

The first discovery of Permian vertebrate footprints in the English Midlands was made at the Rock Valley quarry, north of Mansfield, near the Midland Railway line to Worksop. An account of the discovery is contained in a letter written on August 3rd, 1902, by George Hickling, lecturer in geology at King's College, Newcastle-upon-Tyne, to Professor W. Boyd Dawkins of the Department of Geology, University of Manchester. This letter was based on notes made by the Nottingham geologist James Shipman; it is now preserved in the files of the Natural History Museum, Wollaton Park, Nottingham*:

"The footprints were first noticed by Mr. Francis Holmes, Evangelist, of Leicester, while passing the quarry in a train on October 14th, 1897. Mr. Holmes communicated his discovery to Mr. James Shipman, who visited the quarry a week later, on October 21st, when he saw the slab with the footprints in situ . . .

The bed containing the impressions is a sandstone in the middle of the Lower Magnesian Limestone. It is a light reddish massively-bedded sandstone which forms a curious lenticular intercalation in the limestone of Mansfield. Both above and below it passes into the limestone by means of what the quarrymen term a "bastard limestone" — i.e. a mixture of sand and limestone. According to the manager of the quarry — Mr. Gregory — the sandstone at that spot is about 50 feet thick, while above it is some 20 feet of limestone . . .

The footprints occurred in two sets. One set extended across the surface of the bed in a direction 98° (true) or very nearly east and west. It seemed to continue on underneath the part that was still covered by superincumbent strata. The part exposed was 7 ft. in length. At a distance of from 2 feet 10 inches to 3 feet was another slightly divergent set, only traceable however for about 2 feet . . . Altogether there were sixteen prints . . . At a distance of a couple of yards they looked like oysters cut open . . .

On August 31st 1899 Mr. Shipman went to Mansfield and made arrangements for having the footprints taken to Nottingham. He decided not to have the slab sawn up, but to have it sent in one piece to the Nottingham Natural History Museum. The entire slab was about 10 feet in length, but it was cut down to 5 feet 6 ins. by 3 feet, the parts sawn off containing only odd and imperfect impressions."

* I am indebted to Mr. Geoffrey Playle, the Curator, for bringing it to my attention.

Shipman appears to have borne the expense of this quarrying operation personally; his intention of describing the prints was frustrated by his premature death in 1901. Ultimately they were described to the Geological Society of London by Hickling, the account being published in 1906. Hickling considered that they strikingly resembled some tracks described by Pabst, as *Ichnium acrodactylum*, from the Upper Permian of Thuringia, Germany; nevertheless he described and illustrated both the impressions and artificial casts taken from them [208] (Fig.25). Later, in his general review

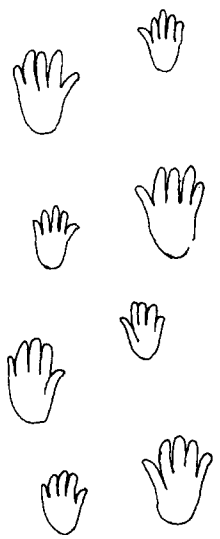

Fig.25. Shipman's original sketch of the Nottinghamshire footprints (*Chelichnus hicklingi* Nopcsa), as redrawn by George Hickling in an unpublished letter.

of British Permian footprints in 1909, he expressed his disapprobation of the allocation of biological names to footprints; his sketch of the Manfield prints is thus labelled "Chelichnoid forms, C1.7". He compared them with the Dumfries-shire footprints and concluded that Permian and Triassic tracks were sufficiently different to be useable in establishing stratigraphic correlations [209]. Swinnerton, in his account of the "Palmistry of the Rocks" in 1912, referred to the slab and published a sketch of it [218].

The large Mansfield slab apparently never went to the Nottingham Natural History Museum; Hickling noted that it was lodged instead in the Free Public Museum of University College, Nottingham. At some unascertained date it was secured by iron stanchions to the outside wall, close to the door of the Geology Department. When the College moved to new quarters at Highfields in 1928, the slab was forgotten.

In the meantime, Hickling's account attracted the attention of three continental geologists. Baron Ferenc Nopcsa in 1923 concluded that the footprints merited distinction at specific level and proposed the name

Chelichnus hicklingi; he neither examined nor figured the type specimen [130]. Much later, in 1959, Hermann Schmidt, unaware of Nopcsa's work, independently concluded that they represented *two* distinct species, *Chelichnus ambiguus* Jardine and *C. bucklandi* (Jardine) — remarkable since this was a single trackway! [214]. Otto Kuhn gave the prints his attention in both his reviews of footprint literature (1958 and 1963), including a sketch in the former work and citing both Nopcsa's and Schmidt's conclusions, without relating them to one another, in the latter [312, 313].

Late in 1965, after an evening meeting of the Committee of the East Midlands Geological Society in the Nottingham Regional College of Technology (which occupies the site, and some of the buildings, of the old University College), I was shown the forgotten slab by Mr. R. E. Elliott of the National Coal Board. It was illuminated dramatically by the light of his torch; the footprint track stood out clearly and looked most impressive. After permission to do so had been obtained from the Principal of the College, the block was removed to the University of Nottingham for restudy and cleaning. When my failure to discover any specialist in the field made me realise how totally neglected was the study of vertebrate footprints in present-day Britain, I rather reluctantly undertook the redescription of these footprints myself [211] and, my interest thus aroused, afterwards embarked upon further studies of English and North American fossil footprints.

The type specimen of *Chelichnus hicklingi* survived the Geology Department fire of 1970 unscathed; it is now lodged in the Natural History Museum, Wollaton Park, Nottingham, where it will shortly be on display. A newspaper photograph of the slab was published when it was transferred to the Museum [205].

The Rock Valley quarry at Mansfield was re-excavated during the construction of the Mansfield bypass in 1971. Though modern excavating methods are too destructive to yield many useful specimens, a careful watch was kept for footprints by members of the East Midlands Geological Society during the progress of the excavations, but none was forthcoming. There have been no other finds in the Nottinghamshire Permian.

Devonshire

Footprints were first found in the Red Rock series of this county by Arthur William Clayden (1855—1944), Principal and Professor of Geology and Physics at the Royal Albert Memorial College, Exeter. Though Clayden was professionally concerned with two different sciences, his principal research was in physics [163]; nevertheless, he was genuinely interested in geology and had undertaken a prolonged, and hitherto fruitless, search for fossils in the New Red Sandstone of Devonshire. When a quarry at Stoke Hill, about ¼ mile east of Poltimore, was reopened by Messrs. Collard and Sons of Exeter in 1908 after some years of closure, Clayden took a party from the College Field Club there and himself made the first discovery of the footprints.

Five specimens were eventually secured, representing three different animals (Fig.26). The imprints on slabs A—C were those of a quadruped, with manus and pes of comparable size and each foot tetradactyl, with three large toes and one smaller. Footprints type D were those of a digitigrade quadruped whose weight was stressed on the pelvic region, the impressions of the pes being much deeper than those of the manus, though all feet were of more or less equal size. Four digits only were impressed (2—5), of progressively decreasing length. The longest trail was of type E (about 1.5 m) similar

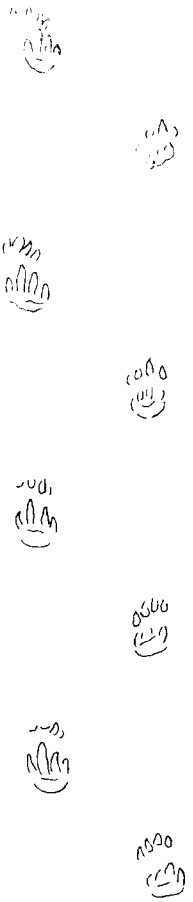

Fig.26. Permian footprints from Stoke Hill, Devonshire, as discovered and figured by A. W. Clayden (1908).

to type D except that digits 2 and 5 were both short, a narrow trackway indicating fast, free movement [161]. The specimens were lodged in Exeter Museum; two further specimens were subsequently acquired by the Sedgwick Museum, Cambridge.

Clayden's discovery was briefly reported and discussed in Hickling's 1909 review [209]: it was mentioned in R. L. Sherlock's account of the Permian

of southern England in 1928 [165] and in J. B. Scrivenor's account of the New Red Sandstone of Devonshire in 1948 [164].

A slab of footprints from the red sandstones of Devon was presented to the British Museum (Natural History) in 1927 (reg. no. R.4895 BMNH) but it has not yet been described; no further discoveries have been reported. A restudy of the Clayden's type material is overdue.

Warwickshire

The earliest mention of Carboniferous footprints from this county occurs in the account of the geology of the Warwickshire coalfield, presented by Robert Douglass Vernon to the Geological Society of London in 1912. Among his list of Permian fossils, there figure footprints from the Kenilworth Sandstones of Cherry Orchard Clay-Pit, Kenilworth, and Coudon-Road Clay-Pit, Coventry. No descriptions or illustrations were given: the specimens were "In the author's collection, Sedgwick Museum, Cambridge" [277]. This citation is ambiguous; however, when Vernon's personal collection was obtained after his death by the Geology Department of the University of Nottingham, no footprint specimens were discovered, and Dr. C. L. Forbes, Curator of the Sedgwick Museum, has informed me that he and his predecessor both sought the footprints in the collections of that Museum, without success. All that survives is a glass negative of one of Vernon's specimens (though the label does not state from which locality); this was in the collection of the late Prof. H. H. Swinnerton of Nottingham University. It is here reproduced (Fig.27) but cannot be identified in the absence of any scale; however, Haubold suggested recently that the prints may be of *Notalacerta* type [220, p.911].

Tracks were later encountered in the Windsor Street Gasworks No. 2 borehole, put down at Windsor Street, Birmingham. Boulton, who first reported them in 1933, noted that the borehole passed the base of the Nechells Breccia (Clent Group) at 830 ft. depth, the footprint-bearing horizon being 10 ft. below this in the upper part of the Enville Beds [263]. Wills later referred to this locality as "Nechells" [278]. Examination of a photograph of the slab by Dr. Haubold and me (1973) showed the tracks to be those of reptiles, among which we identified tracks referable to *Dromopos lacertoides* (Geinetz) and, less certainly, to *Amphisauropus* (cf. *A. latus* Haubold); these latter forms had been called "aff. *Ichnium pachydactulum* Pabst" by Boulton [263, p.61]. Both these identifications supported the Lower Permian (upper Autunian) assigned to the Enville Beds, on the basis of its ichnofauna, by Haubold and me [220, 221].

These are the only records from the Warwickshire Permian. The present whereabouts of the slab illustrated by Boulton is not known.

Staffordshire

In 1912, Walter Henry Hardaker reported to the Geological Society the discovery of a fossil-bearing horizon in brick-clay pits of Messrs. Turner and

Hadley at Hamstead, 4 miles north-west of Birmingham and narrowly inside the county boundary of Staffordshire. The age of the beds was then doubtfully considered to be Permian; they are now considered lateral equivalents of the Enville Beds, which were for long placed in the uppermost Carboniferous, though their stratigraphical assignation remained a matter for some doubt. A long list of forms was reported, all of them assigned to ichnospecies originally described from Germany by W. Pabst:

H1. *Ichnium sphaerodactylum* Pabst.
H1a. *Ichniotherium cottae* Pabst.

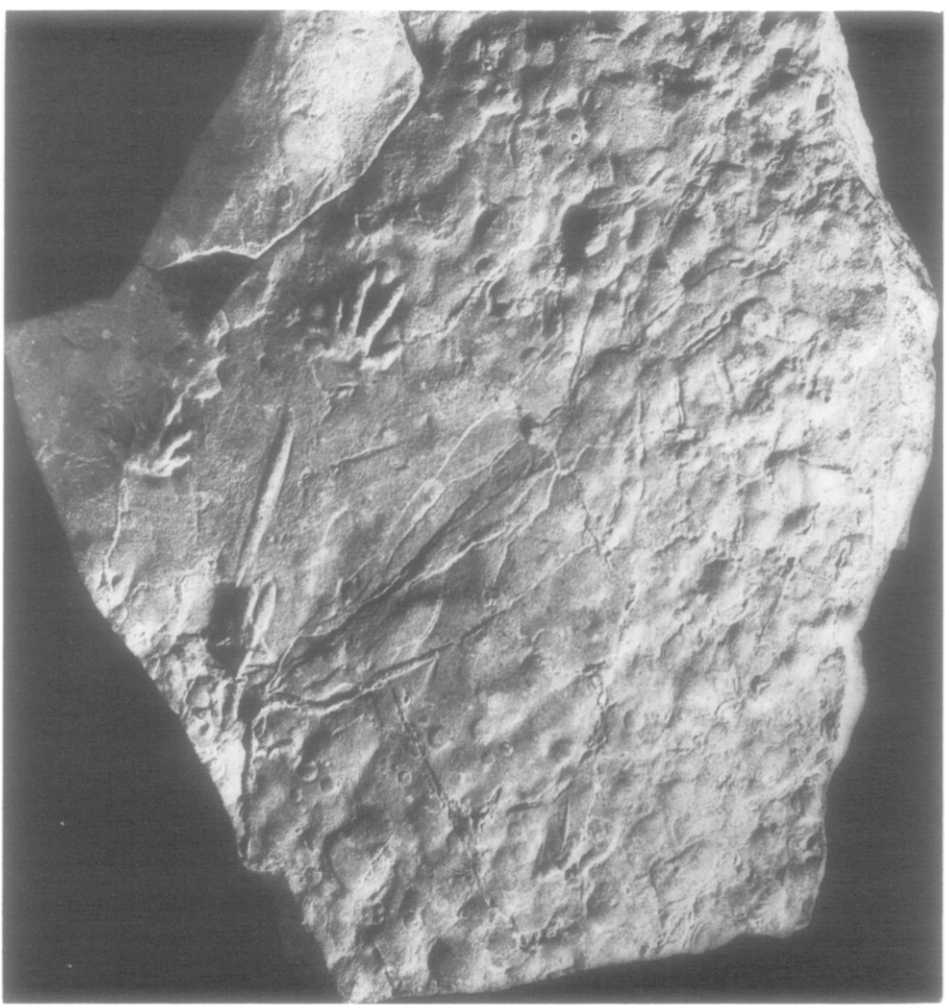

Fig. 27. Footprints from the Permian of Warwickshire. Specimen mentioned by R. D. Vernon (1912); photograph based on a glass negative formerly owned by H. H. Swinnerton, University of Nottingham. Scale not known, but suggested by rain-pitting; specimen lost.

H1b. *Ichnium sphaerodactylum* (*minimum*) Pabst = *Ichniotherium cottae* (*minus*) Pohlig.
H2. *Ichnium pachydactylum* Pabst.
H2a. *Ichnium pachydactylum* (*minus*) Pabst.
H2b. *Ichnium pachydactylum* (*ungulatum*) Pabst = *Ichnium brachydactylum* Geinetz.
H3. *Ichnium brachydactylum* Pabst.
H4. *Ichnium dolichodactylum* Pabst.
H5. *Ichnium gampsodactylum* Pabst = *Saurichnites lacertoides* Geinetz.
H5a. *Ichnium gampsodactylum* (*minus*) Pabst.
H6. *Ichnium acrodactylum* (?) Pabst.

Fossil plants, insect wings and tracks, worm-burrows and castings were also encountered in the quarries and a careful stratigraphical account was given, together with drawings and descriptions of all the footprints [228] (Fig.28). Hardaker did not commit himself concerning the affinity of the trackmakers, saying only that they were "amphibians or reptiles"; however, in the discussion that followed presentation of Hardaker's paper, Baron Ferenc Nopcsa expressed the view that they indicated an animal with a lizard-like body and might have been made by *Protorosaurus*-like reptiles, supporting a Permian age for the rocks [228, p.682].

Baron Ferenc Nopcsa himself reviewed the Hamstead footprints (among many others) in 1923 and proceeded to complicate the taxonomic picture by proposing a new ichnogenus, *Hardakichnium*, with the type species *H. dolichodactylum* based on Hardaker's illustrations, *not* on Pabst's original figures [130]. As Haubold has since pointed out, this name is, as a result, not capable of coherent use since Hardaker's forms are not in fact referable to Pabst's species [229, p.104; 306, p.21].

In 1925, Eastwood et al. mentioned that the footprint bed at Hamstead was located in the Calcareous Conglomerate group of the Enville Beds [227]; the age of these beds was at that time uncertain, but was widely supposed to be uppermost Carboniferous rather than Permian. These footprints were again mentioned by Whitehead et al. in 1927 [236] and, 23 years later, by Wills in the second edition of his "Palaeogeography of the Midlands" [224, p.65]. After a further gap of 20 years, Haubold (1970), in a systematic revision of all Carboniferous and Permian amphibian footprints, tentatively proposed systematic reattributions for two of these prints. *Ichnium brachydactylum* (type H3) of Hardaker was reassigned to a new genus and species, *Amphisauropus imminutus*, proposed in this paper (but based on a German type-specimen). *Ichnium dolichodactylum* (type H4) of Hardaker, which had been made the type of Nopcsa's *Hardakichnium*, was referred to as *Amphisauroides* sp.

According to manuscript notes preserved in the Department of Geology, University of Birmingham, it was the late Dr. Frank Raw of that Department who first discovered footprints in the core from a borehole through the Enville Beds, put down at Slade Heath, about 5 miles north of Wolverhampton. They were encountered at three levels, on core-sections of brownish-red siltstones and sandstones at a depth of between 576 and 584 ft. (ca. 175 m);

Fig. 28. Footprints from the Permian of Hamstead, Staffordshire, figured by W. H. Hardaker (1912) and here redrawn to constant scale. a. "*Ichnium sphaerodactylum*". b. "*Ichniotherium cottae*". c. "*Ichnium pachydactylum*". d. "*Ichnium pachydactylum (ungulatum)*". e. "*Ichnium brachydactylum*". f. "*Ichnium gampsodactylum*". g. "*Ichnium gampsodactylum (minus)*". h. "*Ichnium dolichodactylum*".

the base of the Hopwas Breccia, overlying the Enville Beds, was at 458 ft. (140 m) depth. The only published record of this discovery was an incidental mention in a Geological Survey district memoir by Whitehead et al. in 1928 [237].

The Slade Heath specimens collected by Raw and the greater part, perhaps all, of Hardaker's collection were lodged in the Department of Geology of the University of Birmingham, where they remained unstudied for many years. On the urging of Professor L. J. Wills, I obtained a part of this collection in 1969 as a planned first phase of a research project in which the description or redescription of the whole collection was envisaged. For reasons detailed on an earlier page (p.330), this proved impossible; and, to expedite the completion of at least a part of this research, the help of Dr. Hartmut Haubold was obtained.

Unfortunately, Hardaker's collection was not fully labelled and it was not possible to readily identify the specimens he had figured. However, we were able to identify three ichnospecies with confidence, attributing his types H1 and H1a to *Ichniotherium cottae* (Pohlig) and his types H5 and H5a to *Dromopus lacertoides* (Geinetz); these names have taxonomic priority over those proposed by Pabst. We considered his type H2b to be more correctly designated *Dimetropus leisnerianus* (Geinetz) [220, 221]. In the material available to us from Hamstead, the other forms listed by Haubold were not represented.

The footprint-bearing slabs from Slade Heath, however, exhibited two further types which appeared identical with forms Hardaker had described — *Gilmoreichnus brachydactylus* (Pabst) is presumably Hardaker's type H3 and *Anthichnium salamandroides* (Geinetz) appears to correspond to his type H4. By far the most abundant footprint on these slabs, however, is *Dromopus lacertoides* [220, 221].

These assemblages of footprints, all from the upper part of the Enville Beds, enable firm correlations with equivalent assemblages from the Rotliegendes of Thüringia and show that these beds are of Lower Permian (upper Autunian) date — exactly as Hardaker originally supposed!

Westmorland

The only record from this county is a brief mention in Kendall and Wroot's "Geology of Yorkshire", published in 1924, of the occurrence of presumed footprints in marly layers near Dufton, in the Vale of Eden [294, p.264].

Lancashire

On Thursday, 16th March, 1972 — the day after he had heard me lecture on fossil footprints to the Manchester Geological Society — Mr. R. J. Ireland, of the Mersey and Weaver River Authority, discovered vertebrate footprints for the first time in the Permian of Lancashire. The prints, small and slender, tridactyl, and with widely divergent digits, were discovered in the Manchester

Marl (Eccles Red Beds) in the Haydock Park No. 1 Main Borehole, on a surface of mudstone exhibiting desiccation cracks. Mr. Ireland intends, in association with Mr. Robin Grayson, to publish a full account of his interesting discovery.

Jurassic footprints

Wiltshire

In 1831, George Poulett Scrope, a geologist principally famous for his work on the volcanoes of central France, reported to the Geological Society of London that he had found ripple-marked surfaces of the Forest Marble north of Bath characterised by

"... rolled fragments of shells, corals, spines of echini, and crustacea, by the imbedded remains of fuci, and above all by the frequent intersection of their surfaces by the fresh looking *tracks of some animal*, impressed upon the sand, apparently when left dry by the ebbing of the tide." [280]

Scrope gave no description or illustration and made no guess about their affinity, nor did he even make it clear whether these were tracks of invertebrates or vertebrates. The latter alternative was, however, implied by Barkas, who noted incidentally in his account of Northumberland Carboniferous footprints that

"In 1831, Mr. G. Scrope found several small footprints in the layers of Forest Marble near Bath." [203, p.50]

County boundaries crowd close around Bath; though the city itself is in Somerset, the Wiltshire boundary lies just to the east and the Gloucestershire boundary intersects the Wiltshire boundary only a couple of miles to the north. The Forest Marble here has an essentially north—south strike and crops out to the east of the city. It is probable, therefore, that the locality from which the tracks were obtained was in Wiltshire, much less likely that it was in Gloucestershire and pretty definite that it was not in Somerset.

In the collections of the Yorkshire Museum there survive two slabs of Forest Marble (specimen nos. YM.870 and 871) both labelled "Footsteps, Forest Marble, nr. Sutton, Wilts." Both originally formed part of the extensive collection of William Reed, donated to the Museum in 1878 when Reed was Curator of Geology. "Sutton" is one of the commonest British placenames and, though Sutton Benger, some 15 miles NE of Bath, is possibly the village referred to, this can only be a matter of opinion. However, since Reed was a personal friend of Scrope and certainly obtained specimens from him, it is quite likely that these are the very specimens upon which Scrope based his comments.

The smaller of the two slabs, which shows a single clear track, is illustrated here (Fig.29); the larger slab shows two similar tracks which intersect and overlap one another. The tracks are those of a very small animal, unquestionably a quadruped. The impressions of the fore feet are smaller than those of

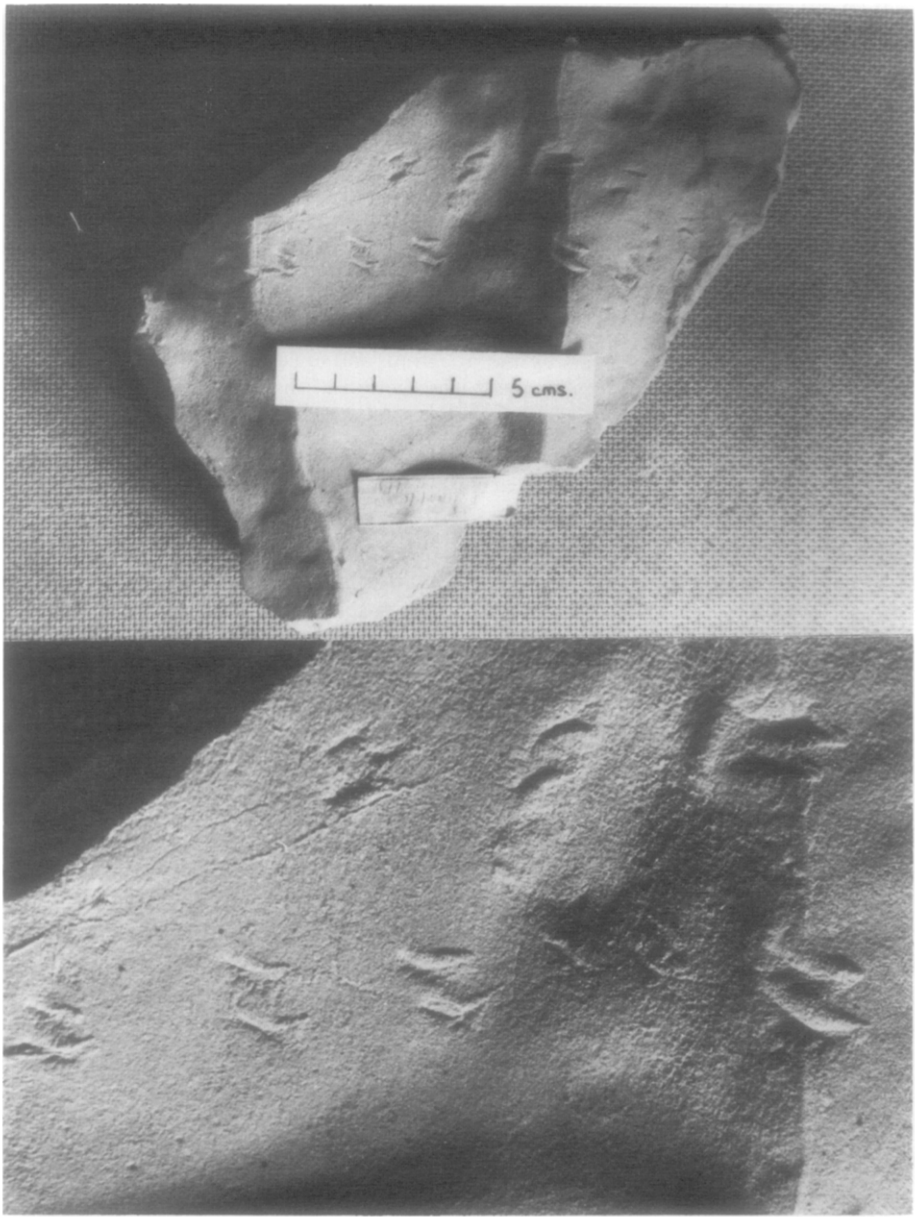

Fig. 29. Tracks on a specimen of Forest Marble (Jurassic) from near Sutton, Wiltshire. W. Reed Collection. Upper: the whole slab; lower: detail of tracks. Photos courtesy of the Yorkshire Museum, York.

the hind feet, and so indistinct that their form cannot be accurately determined; the hind feet, however, show three digits, two (probably digits 2 and 3) clearly impressed and with claws directed forward, at an acute angle to the axis of the digit, and the third (digit 4?) shorter and less markedly clawed. On the basis of their size and character, these are possible lacertoid tracks, but they do not accord closely with any tracks described hitherto. They are superimposed upon low-amplitude ripple marks.

The tracks mentioned by Scrope, whether or not they correspond with those preserved in the Yorkshire Museum, were the earliest to be reported from the British Jurassic and are the only ones on record from southwestern England.

Yorkshire

The first find of footprints in Yorkshire may have occurred around 1895, when a Mr. Rowntree "obtained a footprint from Cayton Bay, which Mr. Lamplugh pronounced to be probably crocodilian" [291, p.92]. The earliest authenticated find, however, was made in 1907, by Harold Brodrick (1908—1946) of Birkdale, Lancashire. Brodrick was a barrister-at-law who had been an enthusiastic and adventurous speleologist in his younger days; he had published several speleological papers, but his footprint studies were to be the only other geological work he was destined to publish [293]. He reported his discovery thus, in a letter to the Secretary of the Whitby Literary and Philosophical Society:

"The two casts which I wish to refer to were found at Saltwick on two separate rocks, both of them evidently fallen from the cliff above, they were both close to the cottage and, in fact, one of them had been used as a portion of a flight of steps leading to a table used by Mrs. Agar's visitors for tea. Both casts are the footprints of a three-toed creature, and are similar to those of creatures, the remains of which have been found in the Wealden beds, and to which the name Iguanodon has been given . . . it is clear, however, that the Saltwick footprints are those of a very much smaller creature . . .

The first of the Saltwick casts indicates a foot with three toes, arranged in the form of a broad-arrow, the greatest length is 7⅞ inches, the palm being 2½ inches in length, thus giving a length to the middle digit of 4⅞ inches, the side digits were about 3⅞ inches in length. The cast is formed of very fine-grained sandstone, and fortunately the whole of the cast is shown. The second cast seems to have been that of a slightly smaller specimen, and is composed of a rather coarser sand-stone; unfortunately, the ends of the digits have been broken so that it is not possible to give measurements. The general shape is the same as the first, but the palm is 1¾ inches long, whilst there is a deep corrugation across it as if the creature had a loose fold of skin under its feet. The total length is 5 inches, but it is possible that the foot was really a little longer. Close to this cast and on the same slab, is the cast of another footprint similar in form but only ¾ inches in its greatest length, this may represent either the footprint of a still smaller creature or it may more probably be a cast of the fore feet of the same one." [286]

This letter was printed in the Society's annual Report, under the excited title "A Find!!!". The discovery was also noted in "The Naturalist" (1908) by "T.S." (Thomas Sheppard, the eccentric but effective Curator of Hull Museum), whose astringent comment was that its title "rather savours of a

Patent Medicine advertisement" [295]. A brief report on the finds was presented by Brodrick at the British Association's Leicester meeting in 1907 [287]. The specimens were lodged in Whitby Museum and casts in Hull Museum (where they were unfortunately destroyed by bombing, along with most of the Museum's collection, in 1940).

Brodrick was fortunate enough to make a further find at Saltwick on his summer holidays in 1908 — a large block, 8 ft. long by 4 ft. broad, on which no less than thirteen casts could be recognised. The horizon from which all three blocks had fallen could not be determined precisely, but Brodrick considered it was within 150 ft. of the base of the Inferior Oolites. The slab, which must have originally weighed about 1½ tons, was cut into sections and transported to Whitby Museum, where the greater part is still lodged [288]: two additional footprint-bearing blocks were later presented to the British Museum (Natural History) (reg. nos. R4830 and R4831 BMNH).

A fuller description of the footprints on the Whitby slab was furnished by Brodrick for the "Proceedings of the Liverpool Geological Society" [289]. The thirteen prints were all tridactyl but showed a considerable variation in form; Brodrick considered them to represent six different creatures but examination of his figures suggests that, at most, four trackways were represented. Two reptiles seem to have progressed across the slab from right to left. One of them had a large pes, tridactyl with digits widely divergent and of fairly constant length (A—B, D—L, K—M), and a smaller manus with three subparallel digits of fairly constant length (C, H, N—O). This reptile appears to have originally been walking on all fours, then to have reared up and adopted a bipedal gait! A single impression of the foot of a tridactyl biped (G) is placed between these prints; this has the broad-arrow outline characteristic of the form Brodrick had described earlier, with a very long central digit. Print E cannot be interpreted. Coming in the opposite direction is a single impression of a more massive tridactyl foot (F), again with the central digit longest. This interpretation of the slab is based in part on Brodrick's drawing (see Fig. 30), in part on examination of the specimens during a visit to Whitby Museum during August 1970, but it may of course be incorrect; Brodrick's more guarded procedure of describing each imprint separately has something to commend it!

In "The Naturalist" for February, 1913, J. A. Hargreaves reported that:

> "In December last, Mr. Arnold Wallis and Mr. Stevenson observed several footprints in fallen blocks of rock at the foot of a cliff 3½ miles north of Scarborough. Further visits were paid to the place . . . The footprints recently found are in blocks of unevenly bedded sandstone, which had evidently fallen from a rather high cliff. They are somewhat weathered. The district where they occurred is difficult to access, and is rarely visited except by shore fishermen and gravel gatherers." [291]

It was recognised that these blocks came from the Upper Estuarine Series. All the footprints were tridactyl, the largest measuring 150 x 160 mm: at least three different types were recognised [291].

Slightly more than a year later, a second report by Hargreaves in "The

Naturalist" recorded further discoveries of footprints by "Messrs. Wallis and Temporley", again in Upper Estuarine strata. The finding of detached blocks this time led to discoveries in situ:

"A cartroad from Burniston to the beach reaches the sands a little over half a mile south of Long Nab, and cuts through the rock containing the footprints. The stratum can be traced for a considerable distance to the north and south, being more persistent than beds usually are in the Estuarine Series, and the footprints, many of which were imperfect, can be traced half a mile north of the cartroad, and a quarter of a mile south, or three-quarters of a mile altogether. They cannot, however, be seen all the way, but only at intervals.

All the perfect specimens are of the usual three-toed kinds, as usual varying considerably in size, some being only 2½ in. in length, and others 4½ or 5 in. One of the largest, on a fallen block, gives a stride of a yard. Some dozens can be seen in the fallen blocks and *in situ* . . .

The impressions *in situ* are in the form of casts in relief on the under surface of the bed, which, in many cases, project beyond the shale beneath, so that the impressions must have been made in the mud forming the shale bed. It is, however, so crumbly and brittle, that it is hopeless to try to get the actual impressions, of which there must have been hundreds. Along with the footprints are curious horseshoe-shaped casts which may have been made by the droppings of these animals. Altogether about a dozen of these were seen." [292]

In their Geological Survey memoir on the country between Whitby and Scarborough (1915), C. Fox-Strangways and George Barrow reported that Percy F. Kendall, then Professor of Geology at the University of Leeds, had identified the footprint bed at Saltwick, which was in the Lower Estuarine

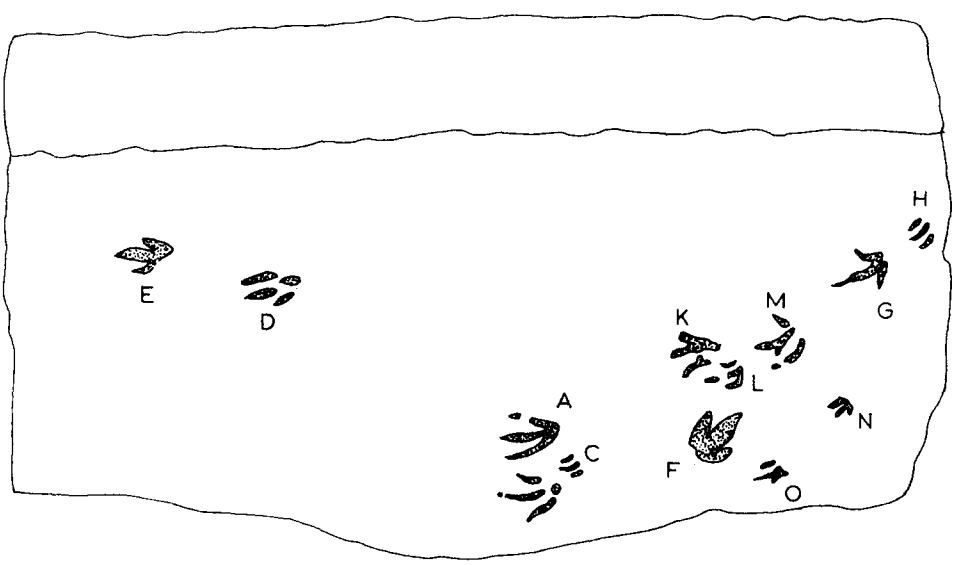

Fig. 30. A large slab with footprints from the Middle Jurassic of Saltwick, Yorkshire. Redrawn after the original figure by Harold Brodrick (1909). Scale: ¾ in. = 1 ft. (approx. 30.5 cm).

Series [290, p.31]. Kendall found that the bed also contained shells of a new freshwater bivalve, later named *Unio kendalli* in his honour [290]. In their "Geology of Yorkshire", published in 1924, Kendall and H. E. Wroot noted that the former had identified the bed "soon after 1907"; they also mentioned that Saltwick prints had been lodged in Leeds Museum and in the Museum of the Scarborough Philosophical Society [294, p.349].

Fox-Strangways and Barrow were also first to record that vertebrate footprints were to be found at Burniston Wyke [290, p.44].

A number of footprint finds were made in the course of a Geologists' Association field meeting in northeastern Yorkshire in August, 1934, under the leadership of Maurice Black, J. E. Hemingway and Vernon Wilson. The finding of a block of Middle Estuarine sandstone with footprints on the foreshore near the Saltpans, Cloughton, was noted, together with finds at Burniston Wyke in what was now being called the "Burniston footprint bed" — footprints of a small bipedal dinosaur with tridactyl feet, about 7 in. in length, together with footprints of a much larger size, also tridactyl, but with the central digit 27 in. long and a double stride of 10 ft. 8 in.! [285, p.298–299].

The most recent discovery was made by a Nottingham University student, Robert D. Boutell, in the disused Peak Alum quarries near Ravenscar. This was a block from what is now called the Lower Deltaic Series, thought to be from a horizon about 21 ft. about the base. The print, broadly tridactyl, appears to correspond with Brodrick's type F: the present author has referred it to *Satapliasaurus* cf. *dzocenidzei* Gabouniya and considers it to be probably that of a herbivorous ornithopod dinosaur, comparable with *Camptosaurus* [213].

Oxfordshire

A slab, exhibiting the footprints of a small lepidosaur, was collected from the Stonesfield Slate (Middle Jurassic) near Burford in 1886 by Mr. C. Pooley and was subsequently presented to the British Museum (Natural History) (reg. no. R.893 BMNH). This has not yet been described in any publication; I hope shortly to prepare a description of it for publication.

Dorset

The occurrence of fossil footprints in the Purbeck Beds is well known. Recent stratigraphical correlations have established that the Middle and Upper Purbeck Beds should be assigned to the Cretaceous, under which heading they are here considered. The finding of fossil footprints in the Lower Purbeck by a Mr. Hardy of Swanage was mentioned by J. C. Mansel-Pleydell in 1896 [187, p.122], but these appear never to have been described. In the intervening 78 years, there have been no further records of footprints from these beds. Recently, however, several tridactyl trackways have been found in the Lower Purbeck strata of Worbarrow Bay; a description by Delair and Brown of these is now in press [183].

Cretaceous footprints

Sussex

The first discovery of fossil footprints in the English Cretaceous was reported in 1846, when the Rev. Edward Tagart presented a specimen to the Geological Society of London, with an accompanying letter to its President. The specimens occurred in the Hastings Sands (Wealden) near Hastings. Tagart's letter was thus dubiously summarised in the "Quarterly Journal":

"The markings in question appear to have been observed by several persons at Hastings; but they have not been found consecutive, or having any distinct relation to one another. They are of large size, the one presented to the Society measuring sixteen inches in length; but there does not appear, either from this specimen, or from the account communicated by the author, any decisive evidence as to their origin." [255]

Though the point was not mentioned in this extract, the complete text of Tagart's letter contained the statement that "Dr. Harwood suspects them to be the footmarks of the Iguanodon" (see Tylor [258, p.247]). Tagart's specimen was transferred to the collections of the Geological Survey in 1911 (reg. no. GS6376): it is here illustrated for the first time (Fig.31).

Wealden footprints were next mentioned in 1850 by Frederick Dixon, in his "Geology of Sussex". He noted "many natural casts and impressions of Reptilian footprints" in Bexhill cliffs [248, p.139] and "fossil casts of large Reptilian footprints on the undersides of a band of stone projecting in the clay cliff at Goldbury Point", Fairlight Clay, Wealden [248, p.145].

In the following year, S. H. Beckles presented to the Geological Society the first of a series of accounts of Wealden footprints, summarised as follows:

"Certain large trifid bodies, presenting a resemblance to the casts of the impressions of bird's feet, are rather numerous in the cliffs to the east and west of Hastings (from the latter locality, Mr. Beckles has now obtained eight specimens, in a limestone containing *Cyrenae*, remains of *Lepidotus* etc. . . .)
Several specimens, detached from the cliffs, have been taken from the beach; but at about four miles east of Hastings, where the cliffs are 200 ft. high, the casts occur at about 40 feet above sea-level. They were found in a stratum of rock, overlying a bed of clay: which latter having been removed by rain and weather, the casts appeared in relief on the under-surface of the rock, just as if they were hanging from the ceiling of a room . One detached block . . . bears four of these trifid bodies in relief; they are arranged with the toes pointing in a uniform direction, so as to make out a nearly perfect square. A distance of 2 ft. 7 in. separates the two in front and 2 ft. 5 in. the hinder two; between the two on the right, from the toe of the hinder one to the heel of the foremost, there is a space of 2 ft. 3 in.; and between the other two, the distance is less by nearly two inches. The largest specimen found has a length of 21 inches." [243]

Beckles gave a second account of Sussex footprints to the Geological Society in 1852. The specimens described were from four localities — from the shore west of St. Leonard's, from White Rock, from the Sluice (about 10 miles west of St. Leonard's), and from excavations for the railway tunnel between St. Leonard's and Hastings — but he noted that footprints were to be found throughout the entire Wealden section on the Sussex coast, a distance of

Fig.31. Footprint of *Iguanodon* from the Hastings Beds (Wealden), Hastings, Sussex, collected by Edward Tagart (1846). Specimen. no. GSb 376. Photo courtesy of the Institute of Geological Sciences.

some 18 miles. All seen were large and trifid: one showed a posterior extension, somewhat like a fourth toe (but, in the present writer's opinion, probably formed by heel-drag). Beckles considered them to be footprints of birds and accordingly termed them "ornithoidichnites" [244].

Two years later he reported again to the Geological Society, four principal series of footprints being described. One of these, from Bexhill-on-Sea, contained 60 impressions in an area of 400 square yards of foreshore exposed at low water; together these formed three principal tracks, clearly of a biped. (A slab containing six of these footprints was displayed at the meeting.) The next two series were collected to the west of Bexhill, the fourth near Galley Hill; impressions were also reported from near Bulverhythe and from between Cowden and Pevensey Sluice. In his conclusions about the animals producing the prints, Beckles was now more cautious:

". . . in using the word *Ornithichnites*, I intend rather to convey an intimation that the trifidal bodies are of organic origin, than to determine the affinities of the animals that produced them: I adopt the term, therefore, provisionally and most cautiously. Although the evidence seems to connect the footprints with the class *Aves*, yet I am not aware that it is such as positively to exclude animals of a different organisation." [245, p.463]

However, he firmly scouted any suggestion that their origin could have been inorganic:

"With the extensive accumulation of these natural casts in may collection, I felt much surprise that men of real science should still pronounce them mere *accidental concretions*. The cause, whatever it was, so uniformly produced the same effects, whether in clay-rock, sandstone, or shale, as to be inconsistent with our idea of an accident. To reject these trifid bodies as organic phaenomena, because they may not happen to come immediately within the types of existing organisation, would be a singular disregard for all those researches which are daily revealing the wonders of former epochs." [245, p.456—457]

In an editorial footnote to the posthumous seventh edition of Mantell's "Wonders of Geology", published in 1857, T. Rupert Jones referred to Tagart's discovery — erroneously citing it as a Wealden footprint "from the shores of the Isle of Wight" [250, p.383] — and briefly mentioned Beckles' studies.

In 1862, a short paragraph in the "Literary Gazette" for 8th March recorded that:

"The fall of the cliff near Hastings, last week, has brought to light an interesting slab of stone, bearing on its surface the clear impression of the foot of a gigantic bird. It has three toes, each of which is about 9 inches long in the tread, with a claw at the end, of perhaps two inches in length. The back of the foot, where the three toes meet as in a centre, does not appear: that part of the foot did not reach the ground. But still further back is the mark made by the point of the spur, or fourth toe. From the point of the middle claw to this mark of the spur it measures twenty-four inches, and in width twenty inches. The whole of the slab is covered with the lines of ripple made by the waves upon soft mud: and there are numerous other impressions more or less perfect of the same bird's claw on the other slabs of stone. The bird which has left us this footprint may be supposed to have been at least twelve feet high, and perhaps much more." [240]

This provoked a letter from "T.R.J." (T. Rupert Jones) in a subsequent issue, in which the bibliographical history of the study of Wealden footprints was summarised. In addition, he noted that "Tracks of like character have also been discovered, by Mr. Hancock, near Cuckfield" and that "At Stammerham and elsewhere, near Horsham, Sussex, ripple-marked sandstones are quarried extensively: these often bear curious and ambiguous markings, some of which may be footprints" [251]. The author discussed the deduction that the prints are those of birds, noting that "fragments of bird bones, not of a large size, are said to have been found in some of the Wealden beds of Sussex" — a report still unconfirmed, indeed probably based on the finding of pterodactyl bones — but goes on to say:

"There are other animals, however, belonging to the "Wealden" and far better known than the birds of that period, that may have had to do with the foot-tracks in question;

namely, the gigantic reptiles, of which we see excellent models in the Crystal Palace Park — the *Iguanodon*, the *Hylaeosaurus* and the *Megalosaurus*." [251]

He points out that the foot of the *Iguanodon* is three-toed and of comparable size, concluding:

"We may therefore be allowed provisionally to refer these tracks to the Iguanodon, who certainly wallowed in the Wealden waters and frequented their sand-bars and mud-banks — who had a great three-toed foot — and who, like some other quadrupeds (such as the Tapir, &c.) may have usually, if not always, planted his footprints uniserially, leaving as his spoor a single row of thick-toed, trifid imprints, sometimes showing the marks both of toes and heels, sometimes of the toes only, according to the firmness of the mud or sand on which he walked." [251]

(It should be noted that, at that time, *Iguanodon* was still considered a quadruped and was depicted as such in the Crystal Palace reconstruction.)

The Geologists' Association visited the Hastings area during 1862 and found "Iguanodon footprints" [247]; and, in the same year, Alfred Tylor read to the Geological Society of London an account of a footprint found in a fallen block of sandstone from the cliff a little west of Ecclesbourne Glen, near Hastings:

"The peculiar interest of the plaster cast now exhibited by Mr. C. S. Mann, of Eltham, . . . is, that it represents what I believe to be the hind foot of an Iguanodon, resting upon a ripple-marked surface of sandy mud sufficiently hard to retain an exact impression. The pressure of the foot has raised the sand surrounding the impression about half an inch above the ripple-mark, at the same time turning over some shells of the genus *Cyrena*, which may be seen in the disturbed mud." [258, p.249]

He provided a coast section showing the localities from which footprints had been reported and mentioned finds in thin sandstones at Biggs' Farm, near Cuckfield; these came from higher in the Wealden series, probably from the Wadhurst Clay [258].

In 1865, the lodgement of an *Iguanodon* footprint from Sussex in the collection of Liverpool Museum was reported in the "Proceedings" of the Liverpool Geological Society; the specimen came from the collection of the great vertebrate palaeontologist, Gideon Mantell [253]. After this, no records of footprints from the Sussex Wealden were published for over 40 years. In 1907, an iguanodont footprint was found during excavations for a waterworks at Crowborough. A note of this discovery was included in the report of a Geologists' Association excursion to the area by R. S. Herries [249]; the specimen is said to have gone to Brighton.

Ten years later, in 1918, Anthony Belt discussed finds at Hastings, Cooden, Bexhill, Bulverhythe, Govers, Ecclesbourne and Fairlight in a paper presented to the Hastings and St. Leonards Natural History Society [246]. In 1921, footprint-bearing slabs from Galley Hill, Hastings, were presented to the Geological Survey Museum by H. W. Wilson (reg. nos. GSM 37460 and 37961); and the list of "Fossils exhibited" to the Geologists' Association in 1922 includes "*Iguanodon* tracks from the Lower Wealden near Bexhill" [241].

In 1924, the Rev. J. C. Thompson informed the Hastings and St. Leonards naturalists of the discovery of footprints at Galley Hill, not only of an *Iguanodon* but also of an animal leaving more elongated and slender prints, possibly a megalosaur [256].

In June 1925, another Geologists' Association excursion visited the Hastings region:

"Beyond the point (Little Galley Hill) and the stack, large footprints of *Iguanodon* can be seen, on the sandstone blocks on the foreshore. Some good specimens of these are preserved in Bexhill Museum." [252, p.304, fig.24]

The footprint horizon was recognised as located in the Ashdown Sands division of the Hastings Sands. In the following year, Osbourne White's Geological Survey memoir on the region noted "Saurian footprints" in the foreshore at Cooden and Bexhill and in the geological collections of the museums of Brighton and Bexhill-on-Sea [254, p.14].

Three years later, N. F. Ticehurst read to the Hastings and St. Leonards Natural History Society a detailed account of *Iguanodon* footprints exposed by a cliff-fall near Bulverhythe [257]. After this, no further new discoveries were reported until 1965, when "?Animal tracks" were discovered by a Geologists' Association excursion in the Middle Ashdown Beds at Jarvis Brook, in East Sussex [242, p.317]. No recent studies of the Sussex footprints have been published.

Haubold (1971) has pointed out cogently that it is undesirable that footprints should be given a generic name based upon osteological remains and suggested instead that the available ichnogeneric names *Struthopus* Ballerstedt or *Wealdenichnites* Kuhn might be chosen for the *Iguanodon* footprints [306, p.87]. The fact that the zoological code of nomenclature does not permit such a procedure is an indication of the undesirability of classing footprints under that code (for fuller discussion see Sarjeant and Kennedy [329]).

The Isle of Wight

The first record from this Island is in a letter published in the "London, Edinburgh and Dublin Philosophical Magazine" in 1846, by S. M. Saxby, who reported the discovery of footprints in fallen blocks of Greensand on the foreshore at Ventnor, Isle of Wight. Four types of impressions were noted (Fig.32): large, tridactyl prints around 7 in. in length, with three long, widely divergent digits; smaller tridactyl impressions, shaped like a fleur-de-lys, for which no dimensions were quoted; webbed tridactyl imprints, 2¼ in. long, with a pronounced "heel"; and a plantigrade, tetradactyl impression with very short, blunt digits, 2¾ x 2¼ in. The prints were indented into "the flinty-blue rag which forms the bed of the freestone" [197, p.310]; the natural separation of the two beds by weathering processes could not be matched artificially by Saxby, even when he was aided by qualified masons. Saxby's description does not make it clear whether the blocks he was studying came from the Lower or the Upper Greensand and his petrographic terms

do not enable any conclusions to be drawn; however, it appears most probable that the specimens came from the *Lower* Greensand. This is the youngest bed in the British Mesozoic from which fossil vertebrate footprints have been reported; unfortunately, the specimens are lost and there have been no subsequent records from these beds.

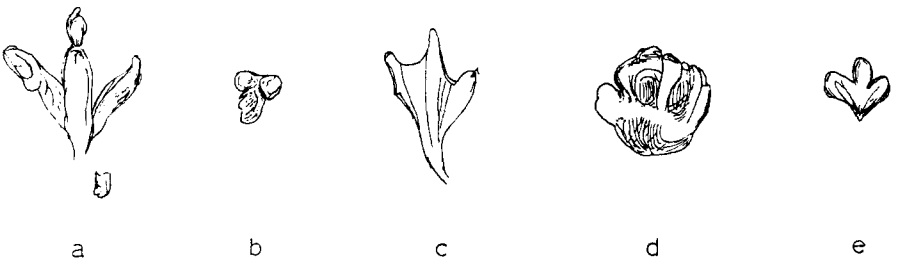

Fig. 32. Footprints probably from the Lower Greensand (Cretaceous) of Ventnor, Isle of Wight, as figured by S. M. Saxby (1846).

In 1851, S. H. Beckles noted incidentally, in an account of fossil trifid footprints from Sussex, that "Dr. Mantell has discovered a specimen in the Wealden of the Isle of Wight" [243]. This discovery was reported by Mantell, in 1854, in a revised edition of his account of the geology of the island:

> "This specimen is a solid tripartite mass of fawn-coloured sandstone: the middle process is fifteen inches, and the two lateral projections are twelve inches in length; the greatest thickness is six inches; the processes are laterally compressed and rounded at the extremities, and united to one common base." [195, p.238]

He went on to comment:

> "As the origin of these singular concretions is very problematical, every specimen should be preserved; and if several occur on the same bed, their relative position should be ascertained." [195, p.238]

In 1862, Beckles gave an account of large trifid casts from the Wealden near Compton Bay which he compared carefully with the hind foot morphology of *Iguanodon*, though conscientiously noting "It is certain that other Dinosaurians beside the *Iguanodon* had the same modifications of structure; and we must not refer those pachydactylous trifids to that animal exclusively" [193, p.446] — a point sedulously ignored by most subsequent Cretaceous researchers! He also discovered much smaller trifid casts (3 in. x 3 in.) about halfway between Brook and Brixton, "set about 15 inches apart, on a sandstone band exposed only at very low water" [193, p.446], and mentioned further occurrences of footprints at Hanover Point and Sedmore Point [193, p.443].

Beckles' discoveries were referred to in Damon's "Geology of Weymouth" [179, p.117], in the Geological Survey memoir on the Isle of Wight published in 1889 [194] and in Osbourne White's shorter account of the island's

geology in 1921, when the occurrences at Hanover and Sedmore Points gained specific mention [196]. No further finds have since been reported.

Dorset

In a footnote to his account of Sussex Wealden footprints (1854), S. H. Beckles noted that:

"In the [London Geological] Society's Collection there is also a large slab of Purbeck limestone, the surface of which is shaly and covered with coarse fucoidal(?) markings. In this shaly portion are two large, trifid, pachydactylous footprints, resembling those from the Wealden, each measuring 12 inches in length." [245, p.456]

This discovery was mentioned in Damon's "Geology of Weymouth" in 1856 [179, p.117] but no full account of the prints was ever published. In 1862, however, Beckles reported to the Geological Society of London his finding of natural casts of footprints in the Wealden beds of Swanage Bay, at about 200 yards from the western end of the Wealden cliff:

"They occur in two bands of sand-rock, usually about 1 foot thick, separated by about 20 feet of clay, and coming down to the seashore with the other beds. These casts are of the usual thick-toed trifidal shape, and of the usual size — about 15 inches long." [193, p.446]

In the same year, "T.R.J." (T. Rupert Jones), in his letter to the "Literary Gazette" quoted earlier, commented:

"The strata of Durlstone Bay, near Swanage, should be examined closely for these interesting traces of the gigantic land animals of the later Mesozoic period." [251]

It is probable that "T.R.J.'s" suggestion resulted from his awareness of Beckles' earlier discovery; certainly he was to prove a true prophet for, whilst there was to be only one further record of Wealden footprints from Dorset, finds in the Purbeck strata of the Swanage region have been many and important.

The last discovery of Wealden footprints to be reported was at Worbarrow Bay, where J. C. Mansel-Pleydell discovered them in 1888 in association with dissociated remains of *Iguanodon* [186]. The exact nature of these footprints and their lodgement, if indeed they were collected, is unknown. As well as being the last to discover footprints in the Dorset Wealden, Mansel-Pleydell was the first to record them from the Purbeck Beds of that county. He published the first description in 1896, basing it on an examination of two slabs formerly in Corfe Museum and then transferred to the County Museum in Dorchester; the footprints displayed were firmly attributed to *Iguanodon*. At the conclusion of his paper, he noted:

"Since this paper was read, I have secured a slab showing the actual footprint of a Purbeck Dinosaur from the Upper Purbecks. Mr. Hardy of Swanage, tells me that he has seen similar footprints in the Lower Purbecks as well, if this is the case we have evidence of *Ornithichnites* during the whole of the Purbeck series. Their occurrence in the Oxford and Kimmeridge Clays shows a vertical range from the Middle Oolites to the Lower Cretaceous." [187, p.122]

(This reference to footprints from the Oxford and Kimmeridge Clays is surely erroneous: the nature and depositional condition of these sediments renders any emplacement of footprints of terrestrial creatures highly improbable and makes their preservation, even if emplaced, in the highest degree unlikely.)

In 1904, Sir Arthur Smith Woodward, in an address to the Bournemouth and District Society of Natural Science, referred to the recent discovery of a stone bearing *Iguanodon* footprints which had been built into the wall of a cottage! The stone had been extracted by the owner, who partially pulled down the cottage in the process, and it was presented to the British Museum (Natural History) [166].

Five associated *Iguanodon* footprints, impressed into a slab of the Purbeck "Roach", were discovered in Lander's quarry at Gallows Gore, near Langton Matravers, about 1929 and were ultimately obtained by Mr. Sheasby of Corfe [184]. No account of these was published. Indeed, no further footprint discoveries were described in print until 1933, when J. Bernard Calkin reported, in a letter to the journal "Discovery", the finding of a surface in the Pink Bed (Middle Purbeck) in a quarry at Herston which exhibited four parallel uniformly directed lines of *Iguanodon* footprints; Calkin considered them to represent the tracks of two animals [176]. Unfortunately, these fine tracks were destroyed by a high-explosive shell during the Second World War [188].

Two associated pentadactyl footprints, possibly manus impressions of an *Iguanodon*, were procured before 1939 from the Pink Bed in a quarry, now abandoned, near Acton, Langton Matravers parish, by Mr. W. J. Haysom of Langton Matravers, who cemented them into a path in his garden. No account of these was published for many years [184] and, although other discoveries were certainly being made, it was not until 1957 that an article in the "Swanage Times" for 31st July, "Monster Finds in Dorset", refocussed attention on the topic [167]. One of the specimens from this find was placed on display in the newspaper offices; others were sent to Brighton and to Bristol. The article and exhibit greatly stimulated local interest in the fossil footprints of the Isle of Purbeck. One consequence was that Mr. Ernest F. Oppé of Worth Matravers compiled a list of Purbeck footprint specimens on display or preserved; this was included (and supplemented) in a general account of Mesozoic reptiles from Dorset published by Mr. Justin B. Delair in 1960. Delair also noted that:

> "Much more recently (1959), other tridactyle footprints have been brought to light in the Purbeck 'Roach' bed in Mr. Reginald Cobb's quarry at Acton, Langton Matravers, while large and small tridactyle footprints have just been discovered in the 'Roach' layer in a quarry in the Spyways area of Langton Matravers parish." [180, p.79]

Further discoveries of vertebrate footprints were recorded in the "Bournemouth Evening Echo" for 17th January, 1962, alongside a photograph [168]. The footprints had been discovered in Messrs. Suttle's "Mutton Hole" quarry at Herston; two lines of prints stretched for about 30 ft. across the quarry floor, on a somewhat fissile rock surface. These were mentioned in an editorial in the "New Scientist" for 25th January; the small interval (about 2 ft.)

between successive impressions was noted and, on the assumption that the two lines represented opposite feet of the same animal, it was remarked that the animal must have "moved very ponderously indeed" [170]. These comments attracted a short response from Mr. John Swaine of Swanage, who had observed that a third, quite separate line of prints, paralleling the others, was also present on the same bedding-plane surface. He suggested that the short stride resulted from "the animal walking up what was then a steep incline; its weight was clearly taken on the ball of the foot", noting that "Where the depressions left are up to 2 in. deep, the heel marks are so shallow as to be barely distinguishable" [191].

The Herston footprints were examined by Dr. Alan J. Charig and Mr. B. H. Newman, of the British Museum (Natural History); a short article by them, incorporating a plan of the prints, was published in the "New Scientist" for 3rd May of that year [178]. By this stage further quarrying had revealed not only that the third line was quite isolated and unaccompanied by a fourth, but also that the two original lines, at first parallel, afterwards diverged! Each line must, therefore, represent the trackway of a single animal. They also pointed out (as had Beckles, back in 1862) that is was quite wrong to refer all the Purbeck and Wealden tracks to *Iguanodon*; the Herston tracks, in particular, were perhaps too small to be referred to *Iguanodon bernissartensis* and were certainly too bird-like, not having the fleshy pads to be expected on *Iguanodon's* feet [178]. Some of these tracks were featured when Charig, Newman, and C. A. Walker mounted a display of Dorset Purbeck tracks from the Museum's collections at the Geologists' Association Annual Reunion during the autumn [175]. The fuller account of these footprints promised by Charig and Newman has never been published.

Three weeks after the "New Scientist" article appeared, the "Bournemouth Evening Echo" announced "More Footprints of Dinosaurs Found" [169] and on 25th June, 1963, the "Daily Sketch" reported that tracks from Swanage, specifically from Herston, were being transferred to the British Museum (Natural History) [171]. The same story was carried by the "Swanage Times" on 26th July [172] and, rather unexpectedly, by the "Diamond News" of Kimberley, South Africa [173]. The excavation and removal of the trackway was made possible through financial support from Miss H. G. Trechmann as a memorial to her deceased brother, the geologist Dr. C. T. Trechmann. After cleaning, the trackway was exhibited at the Geologists' Association Annual Reunion that autumn before being finally installed at the Museum; the footprints were attributed to megalosaurs [175].

In the same year, Delair published a short paper recording and describing a new form acquired from Mr. A. B. Lander, who had discovered it early in June 1960 in his quarry at Worth Matravers, and reconsidering the pentadactyl prints discovered by Haysom more than twenty years earlier. Both the newly discovered footprints and those obtained by Haysom were made the types of new genera. The former, tridactyl, almost T-shaped imprints with an extremely long central digit (digit II, according to Delair) were given the name *Taupezia*

landeri. The latter prints could no longer be considered as manus impressions of *Iguanodon*; furthermore, their distinctive morphological character was duplicated by imprints discovered on a second slab, of uncertain provenance. Relatively short digits and pronounced sole and heel impressions indicated a habitually plantigrade reptile; the new name *Purbeckopus pentadactylus* was chosen [181].

In 1965 Oppé published his own short book "Isle of Purbeck: Sunny Spaces and Dinosaur Traces", a refreshing mixture of local history and ichnology. A photograph of the tracks in Suttle's quarry was included; even more valuable were three photographs of a trackway in Hayward's quarry at Queensground, Langton Matravers parish, probably again attributable to megalosaurs but, unfortunately, not preserved [188]. During the following year, Delair gave a more precise account of the finds at Suttles' and Hayward's quarries, with a further photograph of the latter. In addition, two more discoveries were reported; tridactyl tracks with an unusually elongated middle digit, probably of *Iguanodon*-like dinosaurs, from the upper part of the "Roach" in Bowyer's quarry, northeast of Worth matravers, and a tridactyl trackway of more familiar "*Iguanodon*" type at Messrs. W. J. and K. W. Norman's quarry, Queensground, Langton Matravers [182]; the latter track was subsequently purchased and extracted by the Hunterian Museum, University of Glasgow, where it is now on display [190] (Fig.33).

Fig.33. Tracks from the Middle Purbeck of Norman's quarry. Queensground, Langton Matravers, Dorset, on display in the Hunterian Museum, Glasgow. (Reproduced by courtesy of Dr. W. D. I. Rolfe and the Hunterian Museum.)

Attention now shifted to Acton. Two partially overlapping tracks of megalosaurian type were found in Lock's quarry in the summer of 1967; these tracks were measured in detail whilst in situ and were afterwards acquired for display by the Royal Scottish Museum, Edinburgh. Shortly afterwards, a further track of similar type was encountered in the nearby Reynold's quarry; this was not preserved, but J. B. Calkin in his book "Ancient Purbeck", published in 1968, gave an illustration of it. The diagram from his 1933 paper was also reproduced here and the Herston finds discussed [177]. The tracks from Lock's quarry were illustrated in a review paper written by Oppé, in collaboration with G. Walkden, for the "Amateur Geologist" in 1969 [189].

On 23rd March, 1967, Mr. Geoffrey Tyers, member of a party of Nottingham Adult Education students led by the present author, found an iguanodont footprint in a block of limestone at Peveril Point, Swanage (see Fig.34). Although the block was not in situ, it was found well out from the high-tide mark and was clearly derived from a limestone band in the Upper Purbeck; it is now in the collection of an amateur geologist, Mr. E. Fuller. This find is discussed in a forthcoming paper [183].

Fig.34. Tridactyl footprint from the Upper Purbeck beds of Swanage, Dorset, collected by G. Tyers, 1967. Photo: the Author. (The hammer is 13 in. long.)

The tridactyl and pentadactyl footprints from Purbeck were discussed in W. A. Macfadyen's "Geological highlights of the West Country" [185, p.143—145] and Haubold illustrated and described *Taupezia* and *Purbeckopus* in his general review of fossil reptilian footprints [306]. The history of the

study of Purbeck footprints has recently been ably reviewed by Delair and A. B. Lander, who reported a number of discoveries of footprints of iguanodont and megalosaurian types in Purbeck since 1967. They also noted the finding of an iguanodont track at Harden's quarry, near Worth Matravers, in the summer of 1970; this was of particular interest since it proved possible to study both impressions and casts. Though the whole trackway (insofar as exposed) could not be preserved, good specimens were acquired for display in the Worcester and Leicester museums [184].

The great majority of fully documented finds of footprints in the Purbeck Beds are from the Middle Purbeck, from horizons now considered attributable to the lowest Cretaceous (Berriasian). Finds in the Lower Purbeck (Upper Jurassic: Portlandian), although reported during last century, have only recently been confirmed (see p.353); the single block thought to be from the Upper Purbeck (discussed on p.357) was not in situ. The lack of footprint discoveries in the Wealden this century must also be noted. The disproportionate concentration of finds in the Middle Purbeck is unquestionably a direct consequence of economic factors, for these are the levels which yield stone suitable for building: if the whole Purbeck sequence were being quarried, reptilian footprints would almost certainly prove to be present in virtually all the non-marine horizons capable of preserving them.

IRELAND

The first discovery of fossil footprints in Ireland was made on the rain-washed pavements of the city of Cork! An observant gentleman named C. B. Newenham noted them in 1852 on a newly laid flagstone brought from a quarry in the Millstone Grit of Kilrush, County Clare:

"seven pair of decided foot-impressions, evidently the track of one animal; they are very regular, about 4½ inches in advance of each other, and over 3 inches apart laterally. Two or three of these feet show three toes pointing directly backwards, which caused some persons to think them at first the marks of a bird: but they are not the walk of a biped, as a bird, with alternate steps; and therefore it was said that the bird was in the act of jumping forwards, bringing both feet to the ground at once and nearly in a line." [296]

However Dr. Haines, who presented an account of the discovery to the Cork Cuvierian Society, had other ideas: he

"thought them the track of a quadruped . . . and probably a reptile: but it was not easy to reconcile the markings to any known mode of progression, and therefore he made a *second examination*, when he *discovered* that there are the impressions of another pair of feet between each of the former, which satisfied every difficulty and proves the creature to have been quadrupedal . . .

The condition of the slab now is, that we have twenty-six impressions instead of fourteen: fourteen large, about 1 inch in length each, and half an inch wide; twelve smaller casts, nearly half an inch long, giving the idea of the impression of one central toe only. These smaller marks incline forwards towards each other, and also lie an inch and a half in advance, and a little within the line of the larger feet. In the original mould, the *right* feet,

both small and large, are constantly slightly in front of the line of advance of the feet of the left side. The distance of the large impressions before the smaller ones by the progress of the animal is about 2½ inches." [296]

The flag was somehow extracted, to be exhibited to the Society. Though it was presumably *not* returned to be pounded flat by the feet of Cork pedestrians, its present whereabouts is unknown. No illustration of it was ever published, nor have any subsequent discoveries of Carboniferous footprints been made in Ireland.

Not until 1946 were Triassic footprints, so abundantly found in England, discovered in Ireland. Even then, all that was found was a single print of chirotherioid type, discovered by Captain Hallam Ashley on a detached block in a quarry at Scrabo, County Down. The print was photographed (unfortunately, not sufficiently well to permit identification) but was not collected [297]. No further Triassic footprints finds have been reported from Ireland.

WALES

The first discovery of fossil footprints in the Principality was made in 1878 by an artist, T. H. Thomas, who noticed them highlighted on a slab "illuminated by the slanting rays of the setting sun" [301], in the northeast corner of the green in front of the church at Newton Nottage, near Porthcawl, Glamorgan. Casts of the footprints were taken soon afterwards; the slab itself was later obtained by Cardiff Museum.

An account of the footprints was presented to the Geological Society of London on 9th April, 1879, by W. J. Sollas, then of the University College, Bristol. The beds from which the specimen was derived are Triassic breccias (the so-called Dolomitic Conglomerate), formed of small fragments of Carboniferous Limestone — a most unusual lithology for the preservation of footprints. Five tridactyl prints, clearly of a biped, were impressed, all digits being strongly clawed. The central digit (III) was longest, the two lateral digits being similar to one another in length but diverging from the central digit at dissimilar angles, digit II at a smaller angle than digit IV. The prints were firmly assigned to Hitchcock's genus *Brontozoum* as a new species, *B. thomasi*, and were considered to be those of "Ornithic Reptiles" related to *Thecodontosaurus* or *Palaeosaurus* [301].

This find was twice referred to briefly in 1881 — by Sollas in an account of the geology of the Bristol district [302] and by W. J. Harrison in his general stratigraphic work [267]. It was mentioned also by A. H. Cox, in an account of the geology of the Cardiff district in 1920 [299]. In 1928, the holotype of *Brontozoum thomasi* was included in a list of type and figured fossils lodged in the National Museum of Wales [300], where it is currently on display. No further discoveries have been reported from the Welsh Triassic.

The only other record of footprints from Wales is a mention by Wedd et al., in their Geological Survey memoir on the Wrexham district, of footprints in the Erbistock Beds (Upper Coal Measures) of Kings Mills pit, southeast of

Wrexham, Denbighshire. The prints were compared with *Ichnium dolichodactylum* Pabst [298]. No figures or descriptions have been published: the specimen was not lodged in the Geological Survey collections and must be presumed lost.

THE BRITISH ISLES: Tertiary and Quaternary

Although Eocene and Oligocene sediments of more or less continental character are widely exposed in southern England, there have been no reports of fossil vertebrate footprints from them. Miocene and Pliocene deposits are restricted in occurrence and of such specialised character that discoveries of vertebrate footprints are in the highest degree improbable.

Though continental speleologists have reported the occurrence of the footprints of cave bears and other animals in the depths of caves, sometimes preserved under a stalactitic crust, I have not located any comparable records from the British Isles. Records of fossil human footprints from caves and mines and from archaeological sites are, in contrast, relatively frequent. (I have myself seen a surface beaten flat by human feet — occasional toe and heel prints could be seen and the surface still retained a "shine" — exposed at Pitnacree, Perthshire, Scotland, in the course of the excavation of a barrow dated by radioactive means earlier than 2,000 years B.C.) Footprints of domesticated animals have also been reported from archaeological sites. However, such observations fall within the province of the archaeologist and therefore will not be dealt with here.

CONCLUSION

The history of the study of fossil vertebrate footprints in the British Isles may be seen, from the above review, to fall into four phases. First came a phase of discovery, lasting from about 1828 to 1857, with attention focussed first on Scotland, then successively on Cheshire, Warwickshire, and other localities. This was a period of excited comment, but of descriptions that were often poor and only occasionally adequate. Illustrations were sometimes excellent (e.g. those in Jardine's massive work) but were quite often wholly lacking (e.g. Haines' Irish footprints). After this, there followed a thirty-year lull, during which few discoveries of importance were made.

Early in the 1880's the interest was renewed, in England at least, largely because of a massive stimulus given by the work of Liverpool geologists, in particular Henry C. Beasley. This phase was brought to an effective end by the outbreak of the First World War and the death of many of the principal workers.

Things thereafter were never again so good, partly because amateur geologists (always the prime discoverers and describers of footprints before and since) were becoming less prominent and less confident, but largely because the rising cost of stone and the availability of cheaper building materials of

other kinds resulted in the progressive closure of the sandstone quarries that were the primary source of fossil vertebrate footprints. Only in Dorset and Sussex have discoveries been relatively frequent during this period; outside these counties, very little work indeed has been done on British vertebrate ichnology during the last sixty years.

The fact that footprints are almost exclusively found preserved as casts on the undersurfaces of hard beds, in sequences where indurated sandstones or limestones alternate with clays, not only means that they are of infrequent occurrence but also militates against their ready observation. (Footprint impressions in the clays themselves are usually so rapidly destroyed by weathering that they are rarely collected or even observed.) Increasing mechanisation of excavation and the rapidity with which operations are now completed makes discoveries unlikely during civil engineering and constructional projects. A resurgence of sandstone quarrying is unfortunately unlikely, in this present era of concrete and "reconstituted stone" building. Thus museum collections will clearly be of critical importance for future studies; many fine specimens remain to be described, many more need to be redescribed or even rediscovered.

The recent studies by Haubold [306, 307] indicate that footprints may provide important data for stratigraphical correlation, as well as affording information concerning environmental circumstances in past continents and the patterns of behaviour of extinct animals. It is to be hoped that the current growth in interest in marine trace-fossils may result in a concomitant resurgence of interest in terrestrial palaeoichnology.

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No comprehensive bibliography of British fossil vertebrate footprints has hitherto been attempted. The two major international bibliographies by Kuhn (1958, 1963) [312, 313] are useful basic sources, especially when used in association with the supplement by Haubold (1971) [306]; but the obscurity of many journals containing references to footprints and the virtual cessation of the study of footprints in Britain over the last fifty years has meant that very many of the references here cited were unlikely to be discovered by anyone working outside Britain and it is scarcely surprising that the coverage in those works was inadequate. The errors in Kuhn's list of Beasley's papers (1958) are here corrected. Newspaper accounts are included wherever known to me, since these frequently contain critical details of finds; however, many must inevitably have been missed.

The majority of references cited have been examined by me, but a few were checked on my behalf by Mr. J. B. Delair or by Mr. A. P. Harvey of the Palaeontology Library, British Museum (Natural History), to whom I am greatly indebted for their assistance in locating obscure works. The very obscurity of so many references discovered means that it is highly probable that some others still remain undiscovered; I would welcome letters from readers drawing my attention to any omissions.

The bibliography which follows is arranged by country and county, since it is felt that this method will be the most useful method to future researchers. Where a reference deals primarily with one area but mentions incidentally another or others, it is indexed under the principal heading and cross-referenced at the end of the other county sections. A final section lists works of general relevance.

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