

An Enigmatic Borehole Core with Triassic Trace Fossils displayed in the Entrance Foyer of the Earth Sciences Department of Keele University

by David B. Thompson

Introduction

Many members of NSGGA will have noticed a large, round, now unlabelled, specimen of red sandstone mounted vertically on the left-hand side of the entrance to the department. Dr Bill Sarjeant (in Tresise with Sarjeant 1997, p.241), in the book "The Tracks of Triassic Vertebrates", provides the only clue in the literature as to its nature and origins: "It was about this time (the 1960s) that another old borehole core changed hands. On a slab taken from a large diameter borehole put down probably for water supply purposes, casts of footprints of two reptiles... were displayed until then (it was) in the possession of Cheshire County Training College".

Provenance

Although the provenance of this specimen is still somewhat unclear, further enquiry reveals a little more detail. Professor F. Wolverson Cope (in letters to the writer in the 1990s) reported that the specimen had been donated to the department by Ms Lawrence, the then Principal of Crewe & Alsager Teacher Training College (founded as a Women's College in 1912; amalgamated 1974, now part of Manchester Metropolitan University). She is said not to have known the origins of the specimen and, upon enquiry by the writer, neither did David S. Scott, later Principal Lecturer and Head of the then flourishing college Geology Department from 1968. He revealed, however, that the core must have been transferred to Keele before that date. According to Dr Mike King of Bristol University (1997, p.160), the *lithology* of the core compares well with that of many other specimens from "the general Runcorn area" (i.e. northwest Cheshire) which are preserved in many British museums investigated by him. Correspondence with Rod Ireland (formerly Chief Geologist of the North West Water Authority), and Geoffrey Tresise (of Merseyside Museums) suggests that the core may be part of a borehole for water supply of the size occasionally cut by the workforce of John Thom & Co., well sinkers, of the Canal Works, Patricroft, near Manchester, in the first half of the 20th century. A further possibility, acknowledged by both correspondents, is that the core was part of one drilled by Ebenezer Timmins & Sons, later Major Arthur Timmins & Sons Ltd, Waterworks Contractors, the Bridgewater Foundry, Runcorn, who were active in that area for over a century. They are known to have been working until at least 1968. The core is thus presumed to have originated from a borehole in Northwest Cheshire and probably somewhere in the Merseyside to Delamere Forest area.

In this context Rod Ireland "is fairly sure" that the only "40-inch" (1.016m) borehole cores known in this area are those of the Eaton Pumping Station No. 1 and No. 2 boreholes (sunk by John Thom Ltd, for Crewe Corporation Waterworks Department to 244.0m (800ft) depth in 1938-9 at National Grid References SJ 5680.6342 and SJ 5672.6341, and located some 700 yards northeast of Arderne Hall).

However, another, possibly large, borehole core, was drilled by Messrs Timmins at Kingswood on the site of the Liverpool CB (?County Borough = tuberculosis) Sanatorium in northwest Cheshire, at SJ 5226.7350, at an unknown date. This may be of 42 inches diameter (1.067m), down to 167ft out of a thickness of 280ft of "Lower Keuper Sandstone", according to the figures quoted on a diagram drawn for the Mid and South east Cheshire Waterboard (undated drawing Z2/11/4, R.J. Ireland, personal communication, October 2000). Alas, this core is only cited as 10 inches in diameter at such depths in another, usually reliable, source (Wray & Earp, 1944).

Previous finds in the likely area of provenance

In 1850 some new vertebrate footprint finds were reported in the Runcorn area by Robert Harkness (1816-1878), later a professor of Geology at Queen's College, Cork. He noted that the commonest prints found were those of rhynchosaurs (lizard-like reptiles) and chelonians (tortoise and turtle-like beasts). He noted that cheirotheroid (sic) (hand-beast) prints were only occasionally found in rocks which were referred to as the "Bunter" Sandstone, a term then covering all the Triassic sandstones of the area prior to the Geological Survey's designation of separate rock units such as the Bunter Pebble Beds, the Upper Mottled Sandstone and the Lower Keuper Sandstone (see Hull, 1860). Harkness cited the locality of his finds as "the quarry at Weston Point". Tresise (1997, p.70) judges this to have been John Wright's Runcorn Boundary Quarry, which was linked by drum lines - the quarryman's name for tramway rails on which stone was transported - which were running through a gully. The latter can still be identified immediately south of the former Runcorn Fever Hospital which had been situated in a politically expedient situation as close to the parish boundary as possible. Maidwell (1915, p.148) appears to refer to this locality. He reported that "when this gully was cut" (some 70 years earlier, i.e. c.1845 DBT) "several fine examples of Cheirotheroid (sic) footprints were obtained. He

noted that these rocks "belonged to the Bottom Rock and Middle Fey zones of the Lower Keuper", horizons which today are assigned to the middle of the Delamere Pebbly Sandstone Member of the Helsby Sandstone Formation (Thompson 1970a, figs. 4 & 6). This gully has been examined recently by the author and Dr Nigel Mountney and it answers well to Maidwell's description. It is here suggested that Harkness' report, and that of Maidwell, refer to the same specimens, localities and horizons. Tresise (in a letter, December 2000) considers Harkness' identifications as very suspect since in the 1850s many kinds of footprint were referred to broadly as cheirotheroid (sic). On the other hand, the writer suggests that since Harkness was so clear in distinguishing rhynchosaur and chelonian prints, his recording of the occasional chirotheroid footsteps as a third type, however few in number, was possibly accurate.

Leaving this problem aside, the only other record of *Chirotherium* sp. from the Runcorn area is attributed to the Liverpool book keeper turned doyen ichnologist, Henry Beasley (1836-1919), whose ledgers record that on May 20th 1911 (Tresise, 1994, and in Tresise with Sarjeant, 1997, p.71), he visited the Manchester Ship Canal Quarry (formerly the North Quarry, Weston). There he noted "prints of the pes and manus of *Chirotherium*, the first I have ever seen from these quarries" (in over 20 years). Frederick Maidwell (1872-1921), a handicraft instructor at the new Balfour Road School in Runcorn, and a committee member of the Runcorn Free Library where footprint slabs were exhibited, succeeded Beasley as the leading Triassic ichnologist in the country, but he never found even one specimen of *Chirotherium* in the local area. Clearly, the latter are not a characteristic of the footprint beds of the Runcorn area. Since 1838 such occurrences have been more commonly reported in the middle of the Helsby Sandstone Formation beyond the Runcorn area - near Storeton in the Wirral - or since 1824 (recognised 1838) in the Tarporley Siltstone Formation in the vicinity of Tarporley and Lymm (Egerton 1838; Tresise, 1993a, b; Tresise with Sarjeant, 1997).

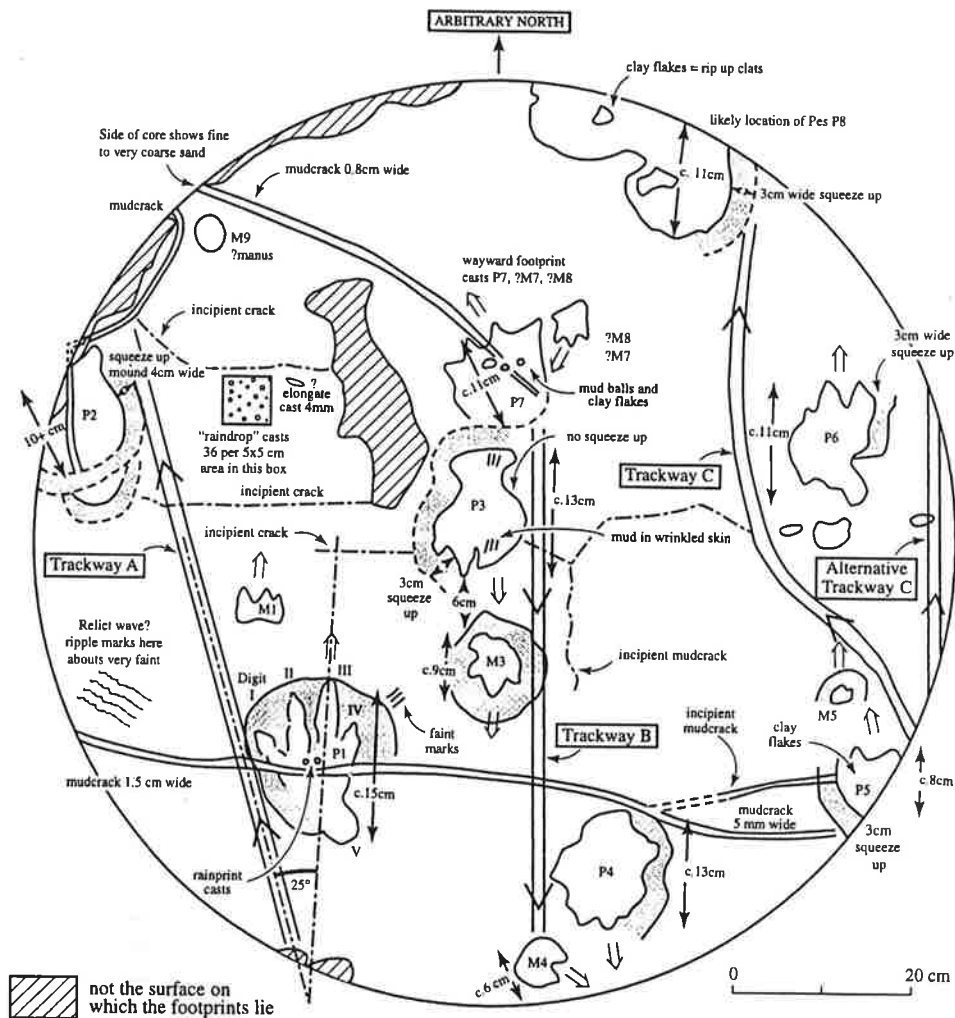
Description and interpretation

The core is actually 1.04m (41 inches) in diameter and 9-12cm deep (Figure 1). It is composed of a bed of medium (fine to very coarse) sandstone resting upon an unknown former thickness of horizontal red mudstone. The sandstone contains several dull-red angular "rip-up" mudstone clasts and a few small mudballs at its base. The undersurface of the sandstone bed contains vertebrate footprints and tracks, desiccation cracks and other small enigmatic structures. It displays several sets of footprints, at least two, and possibly three or more, trackways. King (1997) identified as many as eleven prints, 7 pes (backfeet) and 4 manus (forefeet), though many are not well preserved. Despite this, several pes and manus show clear evidence of their termination in claws on digits I to IV. Poor preservation is thought to be due to the mud-sand interface being quite wet when the original impressions were made. Indeed, around part of the perimeter of most pes, there is a 20-30mm wide depression which, as a cast, represents a squeezed-up mound of muddy sand. This feature is also present to a lesser degree around several manus, though to a less deep extent, reflecting less transmission of weight by these limbs.

Sarjeant (in Tresise with Sarjeant 1997, p.142) suggests that the tracks (presumably A & B of Figure 1) are of chirotheroid type and that the trackmakers probably belonged to different species, though one track is much less well preserved than the other, thus making this evaluation somewhat uncertain. Sarjeant (ibid.) states that "The better preserved track" (see his figures 16.1 and 16.2, the former indistinct and reverse-printed in relation to the original orientation of the core) "appears to be of a type hitherto unreported from England, perhaps *Chirotherium* (now *Isochirotherium*) *hessbergense* Haubold 1970".

King (1997, p.160) also refers the specimens, but less specifically, to *Isochirotherium* sp. whilst citing Haubold (1971). (See Figure 2.) He suggests the presence of natural casts of two left footprint sets (P1, M1; P3, M3), one right set (P5, M5) with an offset manus, four partial pes (P2, P7, P8) and two partial manus (M7-8, M9) (see Figure 1). The well preserved pes prints are c.11-15cm long and 7-12cm wide, the largest and best preserved (P1) of these being at the limit of the size of the largest *Isochirotherium* sp. defined by King (1997; see later). If we assume an arbitrary north to lie at the top centre of the core, Sarjeant (in Tresise with Sarjeant 1997) and King (1997) identified two unspecified tracks of opposing direction (presumably trackway A, to "NNW" and trackway B "north" to "south". In addition, the writer contemplates at least one further trackway ?C in a "south" to "north" direction at the "east" side of the core (see Figure 1). Unfortunately, the precise lengths of the strides and the widths of the tracks cannot easily be measured, but the width of trackway A appears to be of the order 25-30cm, that of B c.30cm, and the stride in trackways A and B are c.60-80cm.

In addition there are many hundreds of very small round, features (2-3mm across, 1-2mm deep), as many as one per square centimeter in many places. These are probably the casts of small raindrops or small hailstones which originally arrived with considerable velocity (as from convectional shower clouds whose initially large droplets were rapidly evaporating as they descended in an very arid basinal environment). They would land upon a still wet but drying hydroplastic surface. More contentiously, these features might be considered to be gas/water escape pits or trace fossils (?burrows or resting traces) made by small invertebrates like water fleas. There are also several desiccation cracks, the largest being c.90cm long, 1.5cm wide and at least 1cm deep, but five other less lengthy curved and irregular, narrow, incipient cracks are also apparent. The "rainprints" succeeded the footprints, and the desiccation cracks post-dated both the footprints and the "rainprints". From this evidence, it is stressed (following Tresise) that the assemblage of prints and structures seen on the Keele core is totally dissimilar to anything displayed on the surviving slabs from the specific Runcorn - Weston area.



Note: the footprints precede the mudcracks; ? the rainprints post-date the footprints

Figure 1. A diagram of the disposition of the vertebrate footprints and other sedimentary structures seen on the underside of the water borehole core of uncertain provenance and horizon displayed in the entrance foyer of the Earth Sciences and Geography department of Keele University.

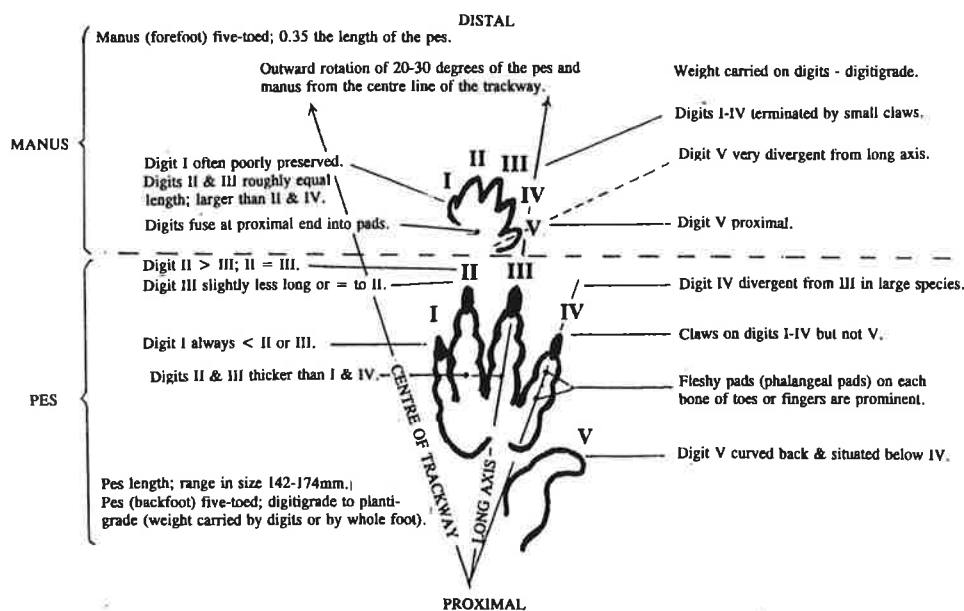


Figure 2. An idealised diagram of a selection of the characteristics by which *Isochirotherium isp.* was identified on the base of the borehole core in the foyer of the Earth Sciences Department of Keele University. The diagram is based on *Isochirotherium lomasi* Baird 1954, and the prints comprise a left set (i.e. pair of forefeet and backfeet) (after King 1997, Fig. 32d, and p.160).

The sequence of events which gave rise to the features of the core was as follows:

- (a) the deposition and consolidation of mudstone upstream in an abandoned channel bed of a braided river at locality X some 15-20 degrees north of the equator in the Triassic trade-wind belt where regional palaeocurrent measurements indicate an effective wind from between ENE and ESE (Thompson 1983).
- (b) the deposition of mud locally at locality Y in a similar pool downstream to the northwest. The mud settles and compacts, at first being wet, but later hydroplastic, and the pond eventually becomes subaerial.
- (c) a group, possibly a herd, of 2m-high carnivorous rauisuchian archosaur reptiles enters the river course, no doubt choosing to walk along the beds of the various abandoned channels in order to move from waterhole to drying waterhole. They walked roughly "SSE to NNW" or "North to South" at separate times, many of their footsteps pushing up ridges in the soft sandy mud and in places churning it up. Other reptiles of similar type moved across this muddy patch either before or after these events. The commonest reptiles of the riverbed, the herbivorous diapsid rhynchosaurs, possibly feeding largely on horsetail plants (King and Thompson 2000, Fig. 23), may have seen the chirotheroids from afar and may have avoided the area.
- (d) at some time after, the centre of this hot arid basin becomes cloudy overhead, possibly thundery, and convectional raindrops or hailstones fall from cumulonimbus clouds. They descended with considerable force upon the hydroplastic surface and the footprints, leaving their distinctive marks on both;
- (e) aridity returns and cracks begin to form in the drying mud as the unrelenting sun bakes the ground; the rainprints dry out completely and the animals desert the area.
- (f) the weather/climate takes a more serious and prolonged turn for the worst either upstream of the immediate local areas X and Y, or in the half-graben basins to the south (the Stafford-Kidderminster or Knowle Basins, or the Wessex Basin i.e. the area within and adjacent to what is now the English Channel (see Figure 3). In either scenario, ephemeral flood waters discharged northwards towards the sedimentary sink of what is now the East Irish Sea Basin, ripping up the now sun-cracked mudstones of locality X and rolling mudstone balls in bed load alongside the aeolian sands which are being reworked yet again by floodwaters.
- (g) the river floodwaters enter the marginal abandoned channels and mudpools at locality Y and lap relatively gently across the footprint tracks, raindrop moulds and desiccation cracks without eroding them. They infill (i.e. cast) them and so preserve them for eternity. This interpretation contrasts with that of Maidwell (1915) who argued cogently and well for the rhynchosaur footprints of his Runcorn area to be casted (in one case at least) by aeolian processes related to the migration of sand dunes during the period represented by at least part of the Middle Fey. This was because he observed mudcurls *in situ* overwhelmed by very round-grained sand and argued that such curls would have easily been swept away by the advent of a more viscous medium like a river current.
- (h) the basin down-sinks; the sandstones and mudstones consolidate and become lithified as a result of chemical exchanges between the minerals and their surrounding groundwaters. These ancient sediments are uplifted repeatedly especially between 65-60 Ma (million years ago) and again c.25 Ma in the Tertiary period, but they survive exposure and erosion. They are miraculously captured by chance in a 20th Century waterborehole, some 242 million years after they had last seen the light of a thundery day.

Horizon

The *lithology* of the core is of a kind which could belong to either the middle of the Helsby Sandstone Formation (e.g. the topmost part of a fining-upwards fluvial cycle of the Delamere Pebbly Sandstone Member; Thompson 1970a & b) of Lower Anisian stage (i.e. Middle Triassic in age, c.242Ma; Benton et al., 1994), or the coarser sandy and fluvial parts of the overlying, generally more flaggy, Tarporley Siltstone Formation, also Anisian in age. (See also Tresise, 1993 a, b). The latter rocks were once well displayed at Red Brow Quarry, near Daresbury (Ireland et al., 1978). Either horizon and age is possible, even likely.

It is now appropriate to ask whether the footprints could be related to any specific horizons in the Eaton No. 1 or No. 2 boreholes cited by Ireland, since the logs of these are recorded in a war-time water-supply pamphlet (Wray & Earp 1944) (No. 1 or No. 2) and in a Survey memoir (Earp & Taylor 1986) (No. 2). Three possible horizons for the occurrence of the footprints in these boreholes were described by D.A. Wray, the on-site geologist (in Wray & Earp 1944, p.32 and Earp & Taylor 1986, p.99-100; Appendix No.1) as follows:

- (a) Horizon C. Depth 3m to 3.7m (10-12.14ft); thickness 0.7m (2ft); in the Tarporley Siltstone Formation of the Eaton No. 1 or No. 2 boreholes (Wray & Earp 1944). "Hard marly sandstone with ripple marked surface and reptilean footprints".
- (b) Horizon C. Depth 3m to 3.7m (10-12.14ft); thickness 0.7m (2ft); in the Tarporley Siltstone Formation of the Eaton No. 2 borehole (Earp & Taylor 1986). "Sandstone, hard, marly; a strongly ripple marked surface with four footprints of a three-toed reptile".
- (c) Horizon B. Depth 73m to 75m (239ft 6in. to 246ft 1in.); thickness 2m (6ft 6in.); in the Helsby Sandstone Formation (formerly the Lower Keuper Sandstone Formation) of the Eaton No. 2 borehole (ibid.). "Sandstone, fine-grained, purplish with green showing sun-cracks and burrows".
- (d) Horizon A. Depth 128-132.6m (420-435ft); thickness 4.6m (15ft); near the very base of the Helsby Sandstone Formation; Eaton No. 1 or No. 2 (Wray & Earp 1944). "Fine-grained marly sandstone with ripple marks and traces

of annelid burrows".

- (e) Horizon A. Depth 128-132.6m (420-435ft); thickness 4.6m (15ft); near the base of the Helsby Sandstone Formation; Eaton No. 2 (Earp & Taylor 1986). "Sandstone fine-grained, marly, upper surface ripple marked many sun-cracks and burrows". (This last is described as "bioturbation of a muddy horizon" elsewhere in Earp & Taylor's text: *ibid.*, p.28)

These features are summarised in Table 1, which also contains observations made by the author on the cores displayed both at Keele and in the entrance hall of the Hurlleston Water Treatment Works, north of Nantwich, Cheshire (Grid reference SJ621552). It is at this last place that it is deduced that part of the Eaton No. 2 core is curated and may be visited by appointment (telephone Rod Nelson on 01270 627458). This latter core is labelled "Piece of 44" Red sandstone core showing ancient tidal rippelmarks and footprints of Cheirotherium (*sic*) mounted and presented by (*sic*) the Corporation of Crewe by John Thom Ltd." "Borehole drilled and tested 1939-40 by Messrs John Thom Ltd, Artesian Well Engineers, Patricroft, Manchester". (Note that there is no reference to this core deriving from the Eaton Pumping Station, or to a particular horizon in that succession, but there is abundant evidence that this core derives from 3-3.7m depth in the Tarporley Siltstones in that borehole. Note, also, that this Eaton core is measurable at 40 inches, 1.016m, wide, not 44 inches as stated in the caption on site).

Horizons/Features		Eaton Pumping Station Boreholes			
		Keele Core; horizon unknown	Horizon A Base HSF-DPSM	Horizon B Middle HSF-DPSM	Horizon C in TSF at Hurlleston
1	Red brown sandstone	(X) (E)			X (E)
2	Purplish-green sandstone			X (B)	
3	Coarse-grained sandstone	(X) (E)			
4	Fine-grained sandstone	(X) (E)	X (A,B)	X (B)	X (B)
5	"Marly" sandstone		X (A,B)		X (A,B)
6	Micaceous sandstone				(X) (E)
7	Mudstone laminae	(X) (E)			
8	Hard sandstone	(X) (E)			X (A,B)
9	Ripple-marked sandstone - wave - current		X (A,B)		X (B)
		? faint (E)			(X) (E)
10	Ripple-marked upper surface		X (B)		(X) (A,B)
11	"Suncracks"	(X) (E)	X many (B)	X (B)	
12	Rain-print casts	(X) (E)			
13	Burrows - unspecified - single - paired	? (E)	X (B)	X (B)	X (B)
					(?) (E)
					(X) (E)
14	Annelid burrows		X (A,B)		
15	Bioturbation		X (B)		
16	Reptilian footprints	X (C)			X 4 (A,B)
		eleven (D)			(X) 21? (E)
17	Two ichnospecies	X (C)			
18	Three-toed prints				X (B)
19	4- or 5-toed prints	(X) (C,D,E)			(X) (E)
20	NaCl pseudomorphs				(X) (E)
Comparisons		Ten features	1 out of 10	1 out of 10	4 out of 10

Key:

x = recorded in log descriptions; (x) = observed in the cores by the author. HSF = Helsby Sandstone Formation; DPSM = Delamere Pebbly Sandstone Member; TSF = Tarporley Siltstone Formation. References: A = Wray & Earp (1944); B = Earp & Taylor (1986); C = Sarjeant in Tresise with Sarjeant (1997); D = King (1997); E = Thompson (this account).

Table 1. Sedimentary structures and features of three horizons in the Middle Triassic (Anisian) rocks of the Eaton Nos 1 & 2 boreholes (Wray & Earp 1944) and the Eaton No. 2 borehole (Earp & Taylor 1986).

These are compared with the structures and features displayed in the borehole core in the foyer of the Earth Sciences Department of Keele University and the core displayed at the Hurlleston Water Treatment works, near Nantwich.

In trying to assign the Keele core to a location and horizon of origin, it is recognised that it displays ten more or less distinctive sedimentary features and has the following characteristics:

- (a) a precise diameter (1.04m; 41 inches) which may relate to the Eaton (40 inch) or Liverpool Sanatorium (42 inch) boreholes, about the latter of which little is known;
- (b) the presence of both desiccation cracks and reptilian footprints;

- (c) "reptilian footprints", a description which may subsume the presence of footprint tracks;
- (d) the likely presence of small rainprint casts rather than "burrows" or "bioturbation";
- (e) a provenance, in the case of the Hurleston example, which includes being drilled for Crewe Corporation Waterworks Department. Part of that core being gifted sometime after 1939 to the Cheshire County Training College (founded at Crewe in 1912), would be consistent with this story.

In these connections, remember that footprints of *Isochirotherium* are known from the Tarporley Siltstones of the Eaton-Tarporley area (Egerton 1838; *I. herculis*), and also from the Lymm area (Tresise, 1997). They are also known lower in the succession in the Helsby Sandstones at Storeton in the Wirral (*I. lomasi*) (ibid; see Figure 2).

In pursuing these enquiries further, it is necessary to note that the Keele core does not display the following characteristics:

- (a) a ripple-marked surface which extends across the whole core (there are, however, very faint wave ripple marks over a small area of core in the "southwest" of Figure 1 when seen in a very oblique light);
- (b) sandstone which is "marly";
- (c) four footprints; indeed there are eleven or more;
- (d) 3-toed prints; rather they are 4- or 5-toed (hence they are archosaurian rather than possibly dinosaurian);
- (e) features which might be loosely described as "burrows" or even "annelid burrows"(unless the rainprint casts have been mis-identified);
- (f) purplish- or green-coloured sandstone;
- (g) prints which can be ascribed specifically to *I. herculis* or *I. lomasi*.

Palaeogeography

Warrington (in Cope et al, 1992, p.99) provides a basic palaeogeographical interpretation for c. 242Ma which will serve to convey an idea of the ephemeral coastal-intertidal and fluvial-aeolian extensional, intraplate basinal desert environments relevant to the Tarporley Siltstones and Helsby Sandstones respectively (Figure 3).

Conclusions with respect to horizon and provenance of the core at Keele

It is certain that some more-or-less 40-inch cores dating from 1938-40 were drilled by John Thom Ltd in northwest Cheshire, very likely at Eaton Pumping Station. The Keele core is slightly, but significantly, larger at 41 inches diameter. At a maximum the Keele core shares only four characteristics with the possible horizons displayed in the Eaton borehole succession as set down in the literature (see Table 1). A modestly positive comparison is possible between the Keele core and horizon C of the Eaton No. 2 core. Alas, the present resting place of part at least of horizon C of the Eaton No. 2 core (from 3-3.7m depth in the Tarporley Siltstone Formation), is convincingly displayed for all to see at the Hurleston Water Treatment works. Consequently the Keele core is unlikely to be related to that horizon.

What of comparisons with the other horizons at Eaton? At a crude measure, the Keele core shares only one out of nine characteristics with each of horizons A and B of the Helsby Sandstone Formation described in the literature for cores from Eaton Nos 1 and 2 boreholes (see Table 1). Any proposed matches or correlations are therefore tenuous to say the least. In any case, the wartime pamphlet (Wray & Earp 1944, p.32) gives details of the engineering aspects of the construction of the pumping station at Eaton and shows that the 40-inch cores were drilled and lined only to 116ft depth (35.34m), i.e. to the base of the Waterstones (the Tarporley Siltstones). Cores cut through the Helsby Sandstones below were cut and lined to 36 and later 33 inches diameter. Hence the Keele core, if from Eaton, could only relate to footprint horizon developed at a natural split on the undersurface of a fine to coarse-grained sandstone unit in the Tarporley Siltstone succession. It would have to be a feature that escaped the eagle eye of the experienced Geological Survey well logger, - Dr Disney Alexander Wray - an unlikely scenario.

The chances that the core came from the Kingswood (Liverpool Sanatorium) borehole cut through the Helsby Sandstone Formation by Messrs Timmins, are considered to be slim; the lithology, though undescribed, is likely to be appropriate; the known details of the provenance are against the hypothesis.

The author concludes, and agrees with Tresise (personal communication December 2000), that the assembly of prints is totally dissimilar to any shown on the surviving slabs from the Runcorn and Weston quarries.

It is shown, however, that the Keele core bears at least one, probably two and possibly three, trackways of the Middle Triassic ichnospecies *Isochirotherium isp.* It is of an appropriate size to have been drilled by John Thom Ltd of Patricroft, and possibly by Timmins & Sons Ltd of Runcorn. A connection is likely to have existed between the Crewe Corporation Waterworks Department and the core's later period of residence in the Crewe Teacher Training College prior to 1968. The core is likely to have been derived from the Helsby Sandstone Formation or a coarser sandstone horizon in the Tarporley Siltstone Formation, both of Middle Triassic age (Anisian). Apart from these facts and conjectures, the true provenance and precise horizon of the Keele core, remains enigmatic and invites the attentions of a future Sherlock Holmes.

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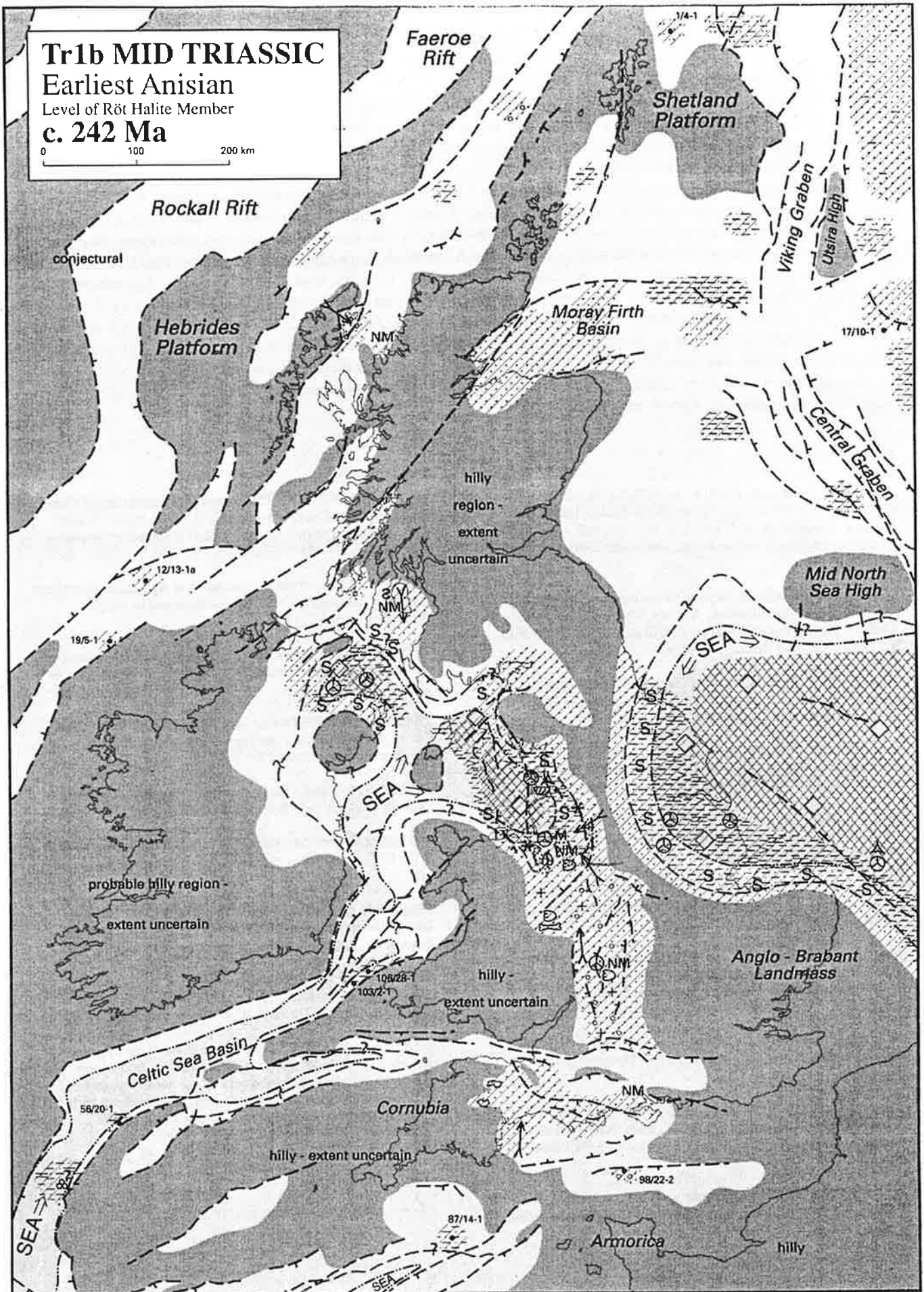
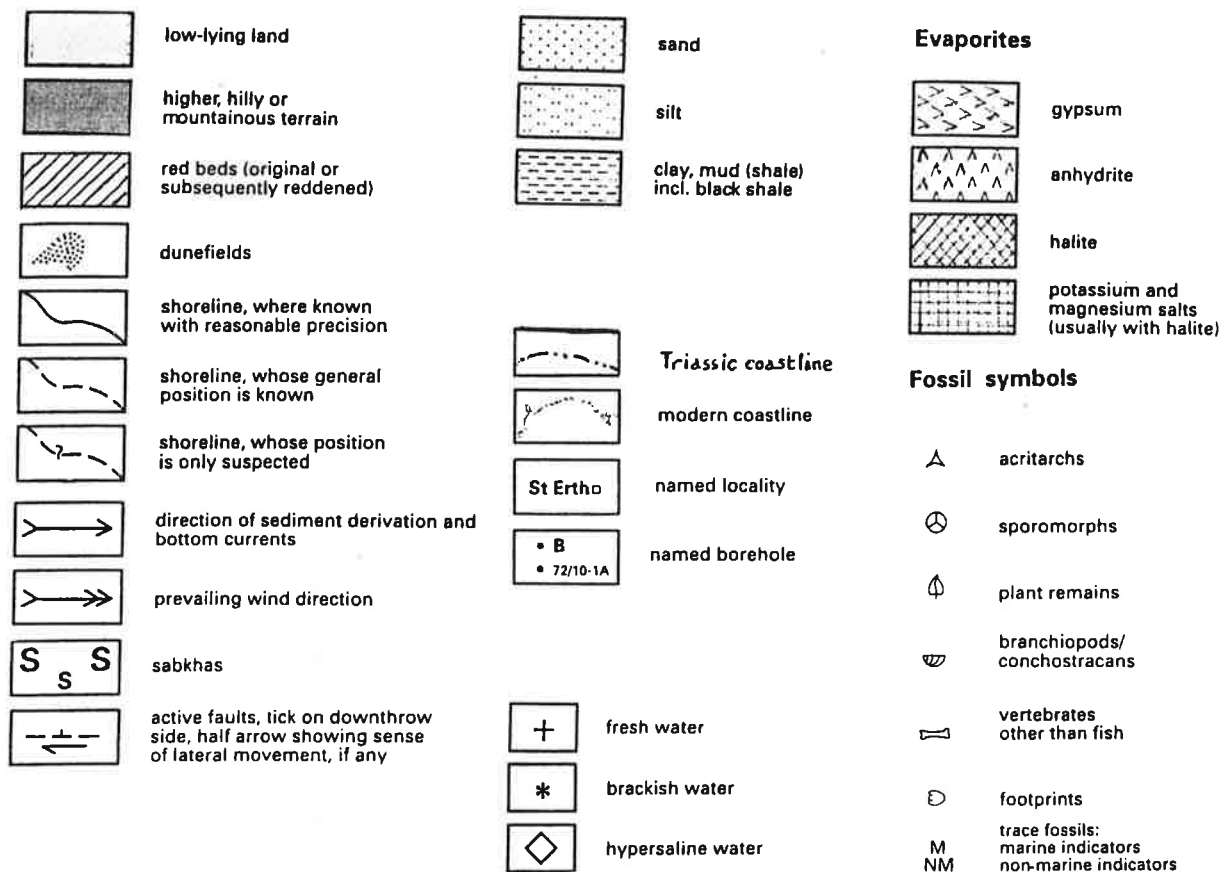


Figure 3. A palaeogeography for c.242 million years ago assuming that the Helsby Sandstone (centre and south of the Cheshire Basin) and the Tarporley Siltstone (north-west of the basin) Formations to be diachronous in the earliest Anisian (middle Triassic).

Adapted slightly from Warrington, G. in Cope, J.C.W. *et al.* 1992. Provided by courtesy of the Geological Society of London.



Key to Figure 3

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