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Article abstract

Vertebrate trace fossils are reported from the upper Parrsboro Formation at Rams Head, west of Parrsboro, Nova Scotia. They occur as casts of tetrapod trackways. The trackmakers thrived in a floodplain setting vegetated with tree ferns. *Pseudobradypus ernerii* Schmidt, represented by three trackways, has previously been reported from Germany. It is interpreted as having been produced by a cotylosaur and occurs in association with several scattered footprints and poorly preserved trackways of *Hylopus hardingi* Dawson; microsaurian-produced ichnotaxa are represented by *Dromilopus quadrifidus* Matthew and *Cursipes dawsoni* Matthew. Assignment of these trace fossils to the late Namurian to Westphalian A (upper Carboniferous) accords with the palynologically deduced age of the strata. As such, the sequence, which hosts the trace fossils, is stratigraphically equivalent to the Coal Mine Point Member of the Joggins Formation.

Vertebrate trackways in the Parrsboro Formation (upper Carboniferous) at Rams Head, Cumberland County, Nova Scotia

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Vertebrate trace fossils are reported from the upper Parrsboro Formation at Rams Head, west of Parrsboro, Nova Scotia. They occur as casts of tetrapod trackways. The trackmakers thrived in a floodplain setting vegetated with tree ferns. *Pseudobradypus ernerii* Schmidt, represented by three trackways, has previously been reported from Germany. It is interpreted as having been produced by a cotylosaur and occurs in association with several scattered footprints and poorly preserved trackways of *Hylopus hardingi* Dawson; microsaurian-produced ichnotaxa are represented by *Dromilopus quadrifidus* Matthew and *Cursipes dawsoni* Matthew. Assignment of these trace fossils to the late Namurian to Westphalian A (upper Carboniferous) accords with the palynologically deduced age of the strata. As such, the sequence, which hosts the trace fossils, is stratigraphically equivalent to the Coal Mine Point Member of the Joggins Formation.

Des traces de vertébrés fossilisés sont signalées dans l'étage supérieur de la formation de Parrsboro, à Rams Head, à l'ouest de Parrsboro, en Nouvelle-Écosse. Elles se manifestent sous forme de sillons de contre-empreintes de tétrapodes. Les créatures qui ont laissé ces traces vivaient dans une plaine inondable dont la végétation se composait de fougères géantes. L'espèce *Pseudobradypus ernerii* de Schmidt, qui a laissé trois sillons d'empreintes, a déjà été signalée en Allemagne. On croit qu'il pourrait s'agir d'un cotylosaurien et les empreintes s'accompagnent de plusieurs autres empreintes dispersées et mal préservées de l'espèce *Hylopus hardingi* de Dawson; des traces fossilisées auraient été laissées par des microsauriens comme le *Dromilopus quadrifidus* de Matthew et le *Cursipes dawsoni* de Matthew. L'attribution de ces empreintes fossilisées au namurien supérieur et au westphalien A (Carbonifère supérieur) corroborerait l'âge palynologique estimé de cet étage. De fait, la séquence qui renferme les traces fossilisées s'apparente au plan stratigraphique aux vestiges trouvés dans le secteur Coal Mine Point de la formation de Joggins.

Traduit par la rédaction

INTRODUCTION

In June, 1997, several trackways of quadrupedal vertebrates were discovered by Cody McLellan in cliff exposures of the fluvial-lacustrine Parrsboro Formation at Rams Head about 4 km from the mouth of Diligent River along the coast west of Parrsboro, Nova Scotia (Fig. 1). The Parrsboro Formation is stratigraphically equivalent to the Joggins Formation, famous for its classic Carboniferous section and for having provided the first evidence for terrestrial tetrapods in early Carboniferous rocks (Carroll *et al.* 1972; Gibling 1987; Calder 1998). Following site investigations at Rams Head in 1997, a portion of the trace fossil-bearing stratum was excavated by personnel of the Nova Scotia Museum of Natural History (NSMNH) and the Fundy Geological Museum (FGM) in order to preserve the trace fossils from rapid erosion by tide and wave action. The best preserved trackways, together with several isolated individual footprints, are now housed at the FGM, Parrsboro. Four ichnospecies are recognized, including scattered and faintly preserved footprints of two microsaurian-produced ichnospecies. Together with associated fossil flora and sedimentary structures, these provide a glimpse of life under subaerial conditions during Pennsylvanian time.

The trace fossils are preserved in convex hyporelief on the base of a reddish-brown fine- to medium-grained

sandstone (Fig. 2). At Rams Head, the largest ichnospecies is represented by four trackways originally impressed in substrate of different consistency and water content. The next largest ichnospecies is represented by scattered individual footprints and as several sets of faintly impressed trackways, the best preserved of which obliquely crosses one of the better preserved larger trackways. The main purpose of this communication is to briefly record and more fully document the morphologies of the two larger ichnospecies.

STRATIGRAPHY, STRUCTURE, AND SEDIMENTOLOGY

The strata at Rams Head belong to the upper part of the Parrsboro Formation, the lowest stratigraphic unit of the Cumberland Group (Naylor and Kennedy 1997; Calder 1998); overturned at the fossil locality, they strike roughly perpendicular to the coastline and dip steeply eastward. Earlier inclusion of the Parrsboro Formation in the underlying Mabou

"It has often happened to geologists, as to other explorers of new regions, that footprints on the sand have guided them to the inhabitants of unknown lands"

J.W. Dawson – *Acadian Geology* (1878, p. 353)

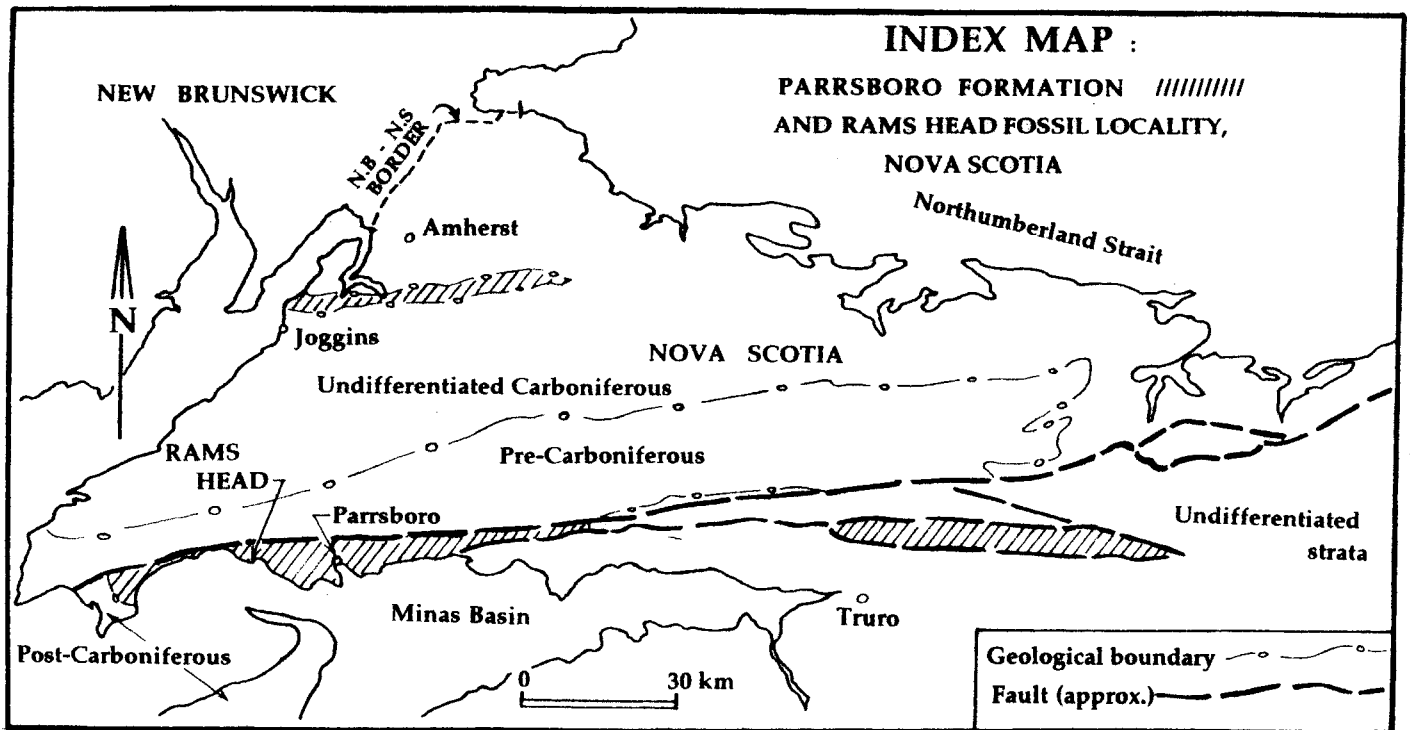


Fig. 1. Location map of the vertebrate trace fossil locality at Rams Head, near Parrsboro, Nova Scotia (after Naylor and Kennedy 1997).

Group (Belt 1965) has not endured. However, the red and grey facies subdivisions proposed by Belt (1965) serve very well to distinguish a lower red facies (ca. 800 m thick) from an overlying "grey facies" (ca. 1700 m thick) in the Parrsboro Formation. Naylor and Kennedy (1997, p. 124) equated the Parrsboro Formation with the lower portion of the Cumberland Group as defined by Ryan *et al.* (1991) (Fig. 3).

The upper part of the (predominantly lacustrine) Parrsboro Formation comprises grey and red mudrock, dark coloured shale and intervals of red and grey sandstone; lack of thick channel sandstone distinguishes it from the (predominantly fluvial) lower Parrsboro Formation, but otherwise poorly drained and well-drained floodplain assemblages are alike in both formations (Naylor and Kennedy 1997). The vertebrate tracks that are the subject of this paper occur in a well-drained floodplain assemblage of red and grey mudrock (dominantly siltstone) that contains rooted horizons, raindrop impressions, desiccation cracks and a variety of other sedimentary structures including dewatering structures (see Naylor and Kennedy 1997; McCarthy 1999).

Results of palynological studies by M.S. Barss (in D'Orsay 1986, p. 119) indicate a late Namurian to an early Westphalian age for the Parrsboro Formation, a conclusion since confirmed by Dolby (in Naylor and Kennedy 1997). Frond impressions of *Alethopteris* sp. (Fig. 4) and *Calamites* sp. stems (Fig. 2) are common at the Rams Head trackway horizon and at various other horizons stratigraphically above and below the trackway locality. The exact location of this studied locality is at the 73.1 m mark at the top of unit #9 in a 152.5 m stratigraphic sequence mapped by McCarthy (1999).

SYSTEMATIC DESCRIPTION

Class: Reptilia

Subclass: Cotylosauria Cope, 1880

Order: Captorhinomorpha Watson, 1917

Ichnogenus: *Pseudobradypus* (*Herpetichnus*) *erneri*
Schmidt, 1963
(Fig. 5, Table 1)

Description: Trackway of a quadruped (Fig. 5) exhibiting pronounced body drag. Footprints plantigrade, manus and pes pentadactyl. Manus smaller than pes and slightly behind; mostly obscured due to near total secondary overlap by pes. Pace exceeds track breadth. Digits I to IV of pes directed forward, digit V obliquely outward; digits II and III are the longest. Internal width (width between tracks) consistent at about 10 cm. External trackway width is 21.0 cm.

The host rock is dark grey, fine- to medium-grained sandstone, the upper surface of which retains traces of an overlying (see also Fig. 6) thin reddish-brown mudstone. Small-scale cross-bedding present in the sandstone about 2 cm below the trackway horizon suggests material transport was downdip, as seen in Fig. 6.

Material: Four trackways, only two of which (#1 - specimen a and #4 - specimen b) are sufficiently well preserved to allow detailed diagnosis. Specimen a consists of ten successive impressions over a distance of 90 cm, each of which, unfortunately, is the result of near total overlap of manus by pes. Specimen b, the smaller of the two, consists of 9 successive pairs of footprints of varying degrees of preservation but provides a partial set of well-preserved footprints (RM - right manus, RP - right pes) that contribute important details. It is located 30 cm above trackway #1 (out



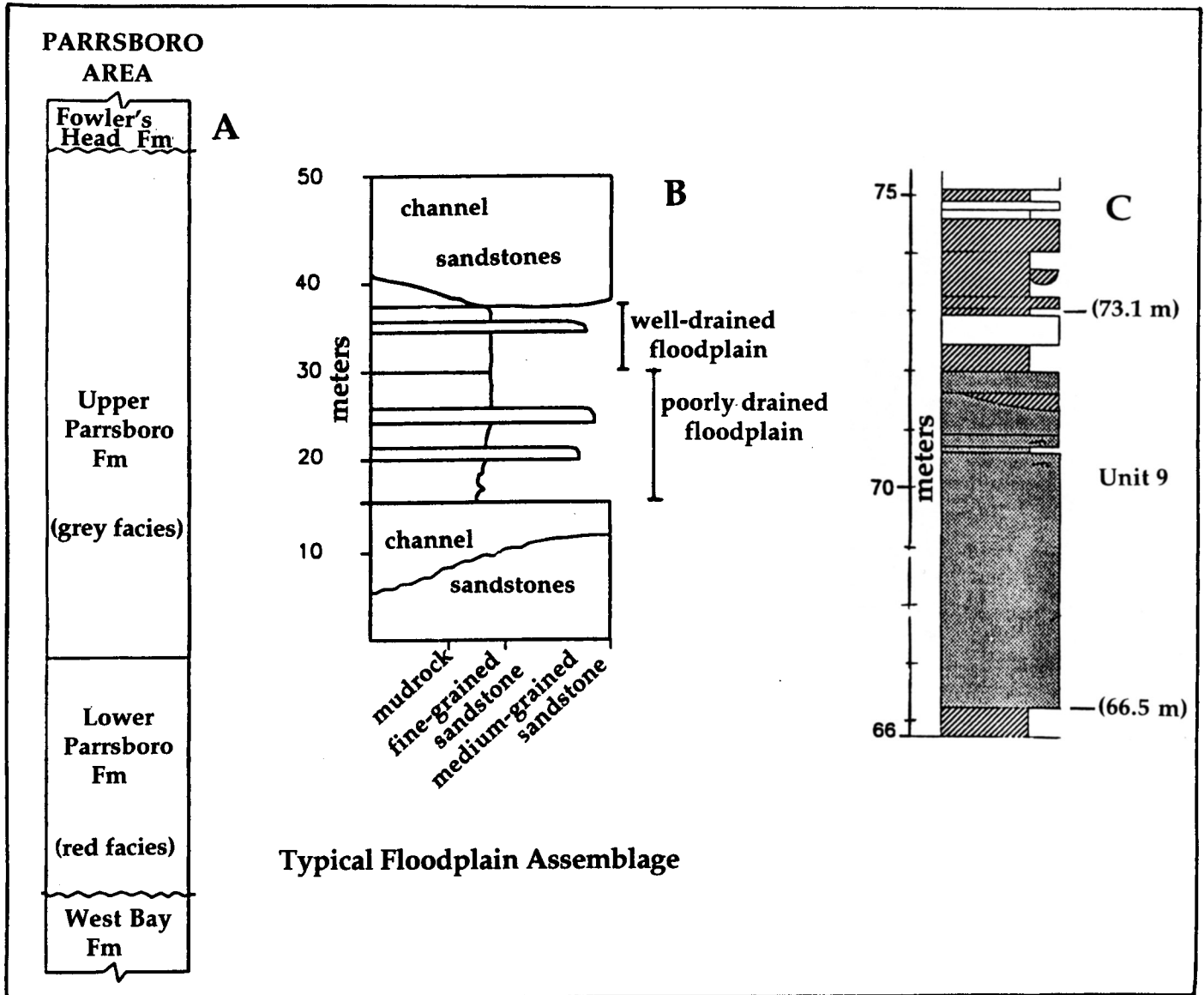


Fig. 3. Stratigraphic scheme applicable to: A) thickness of the Parrsboro Formation and contact relationships with overlying and underlying formations in the Parrsboro area, and B) well-drained floodplain assemblages typical of the upper (and lower) Parrsboro Formation (after Naylor and Kennedy 1997, pp. 117-119), and C) unit #9 (66.5 m - 73.1 m), within a 152.5 m stratigraphic interval at the trace fossil locality in the upper Parrsboro Formation at Rams Head (after McCarthy 1999); cross-hatching refers to relatively finer-grained layers (e.g., siltstone). Trace fossil-bearing stratum (clear) is at the top (73.1 m) of unit #9.

Fig. 2. Photograph looking west and showing trace fossil-bearing rock surface prior to collection in early fall, 1997, by the FGM. Highlights include: 1. The best preserved large vertebrate trackway (trackway #1, left to right, above metre stick) and three other trackways (2, 3, and 4). Trackways #2 and #3 (right to left, below metre stick) are subparallel to trackway #1; a fourth trackway (trackway #4, right to left) is out of view at top right, 30 cm above trackway #1. 5. Numerous small footprints and remnant portions of trackways (not visible at this scale and with this illumination - but for example, see Fig. 8); 6. Location of fossil (*Alethopteris* sp.) fronds; 7. *Calamites* stalk. White lines are glue used to repair fractures. Photograph by K. Adams.



Fig. 4. Photograph shows impression of *Alethopteris* sp. present on trackway-bearing horizon at Rams Head. Coin is 2.7 cm in diameter. Photograph by Tim Fedak.

Table 1. Comparison of measurements of footprints of the holotype *Pseudobradypus (Herpetichnus) ernerii* Schmidt, 1963 from the Ruhrgebiet, Germany, and figured specimens from Rams Head.

	Holotype	Hypotype a	Hypotype b
Pes length (cm)	28 – 30	ca. 10.5	7
Pes width (cm)	19 – 21	ca. 7	6.5
Manus length (cm)	24 – 26	ca. 8.5	5
Manus width (cm)	18 – 20	ca. 5.5	n.d.
Stride (cm)	ca. 100	ca. 18	n.d.
Pace (cm)	—	ca. 18	n.d.
Width of trackway (cm)	ca. 45	ca. 20 (external)	n.d.
Step angle (degrees)	n.d.	60	n.d.
Digit length in cm (manus, pes)			
I	4.0, 2.5	1.0 (pes)	?
II	4.3, 3.2	3.0, n.d.	2.5, n.d.
III	4.5, 4.0	3.0, n.d.	3.0, 2.5
IV	4.0, 3.0	3.0, n.d.	3.5, 2.4
V	3.5, 1.5	2.5, n.d.	3.3, 2.5
Interdigital angles in degrees (pes)			
I-IV	56	50	55
I-V	84	80	80
Interdigital angles in degrees (manus)			
I-IV	68	n.d.	55 (?)
I-V	ca. 88	n.d.	n.d.

n.d. = not determined

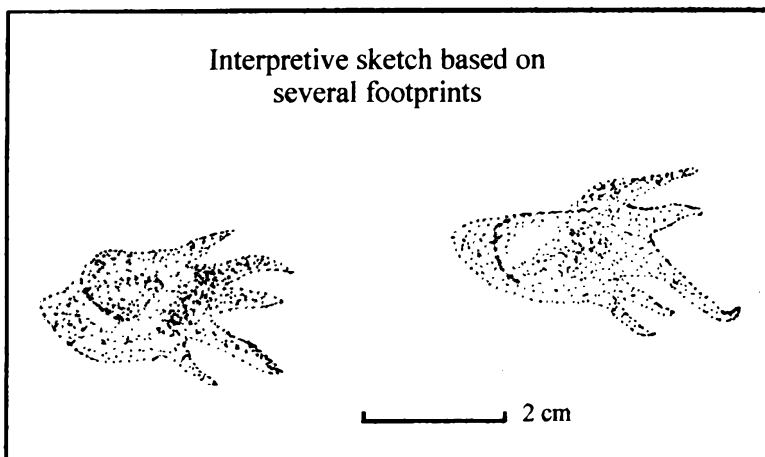
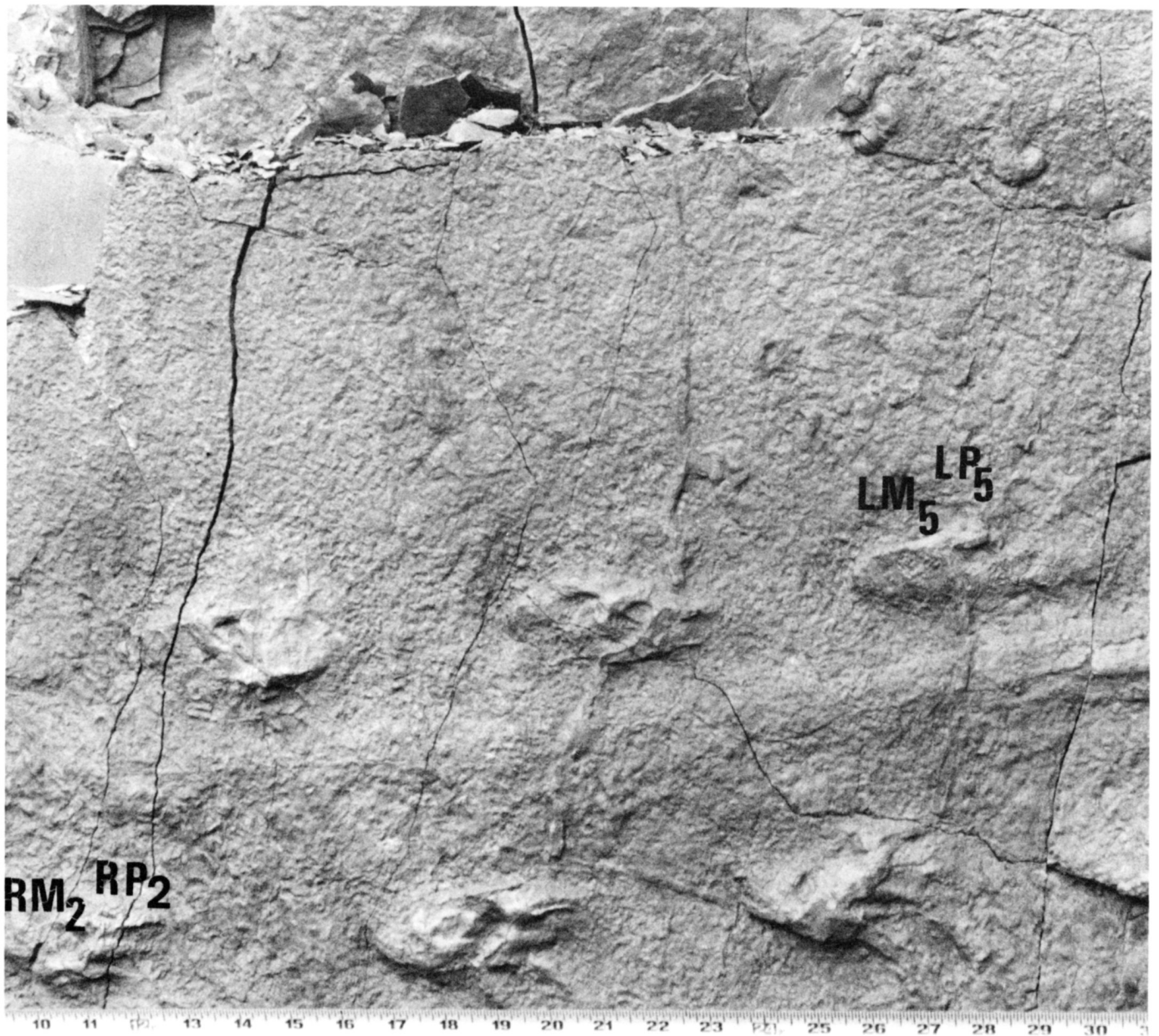


Fig. 5. Photograph shows trackway #1 of *Pseudobradypus (Herpetichnus) erneri* Schmidt, 1963; natural overhead lighting is from the upper left (southwest). Six successive pairs of footprints (RM₂, RP₂ through LM₅, LP₆) of a total of ten in trackway #1 of *Pseudobradypus erneri* shown in Figure 2. Inset shows interpretive sketch of RP₃, RM₄). Based on several photographs taken at different angles of illumination. Scale bar = 2 cm. Photograph by R. Grantham.

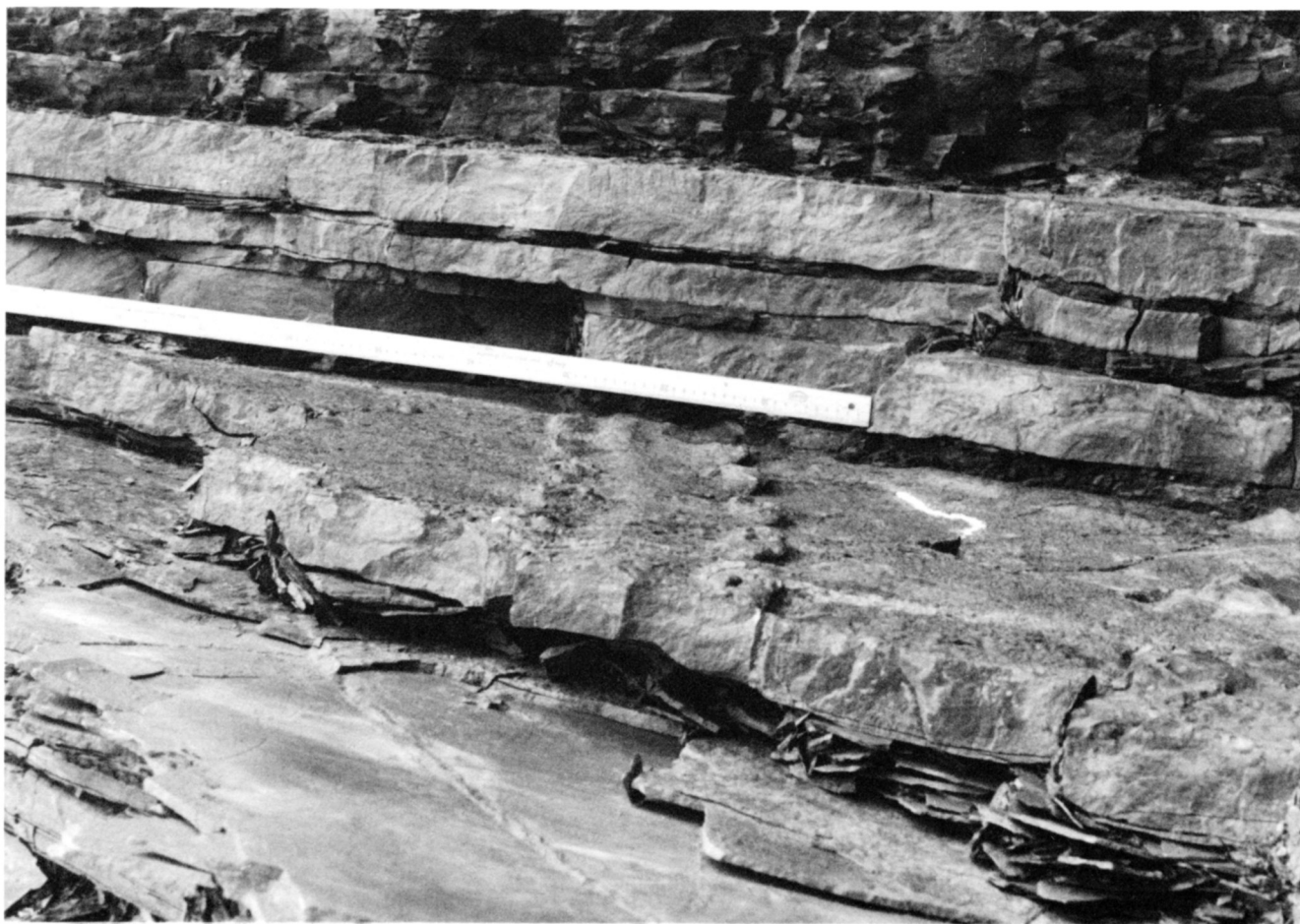


Fig. 6. Photograph of edge-on view of the trace fossil-bearing horizon shows unusual perspective of trackway #1 (*Pseudobradypus ernereri*) and its asymmetrical body-drag (centre of photograph). Overlying (and underlying) this ca. 10 cm-thick sandstone horizon is an approximately 2 cm-thick mudstone (directly under the metre stick) upon the lower portion of which the trackmaker would have traversed and where finer details of the trackway might well have been initially better preserved; curved white line (just below the trackway) is glue-filled fracture (see text for discussion). Photograph by D. Mossman.

of view at top right in Fig. 2) and extends for a distance of 25 cm. Trackways are conserved in FGM on the surface of numerous fitted sandstone slabs and also on a latex mould (peel) (specimen # FGM-999-GF.12) approximately 3 m x 1 m. Total length of trackway #1 is about 90 cm.

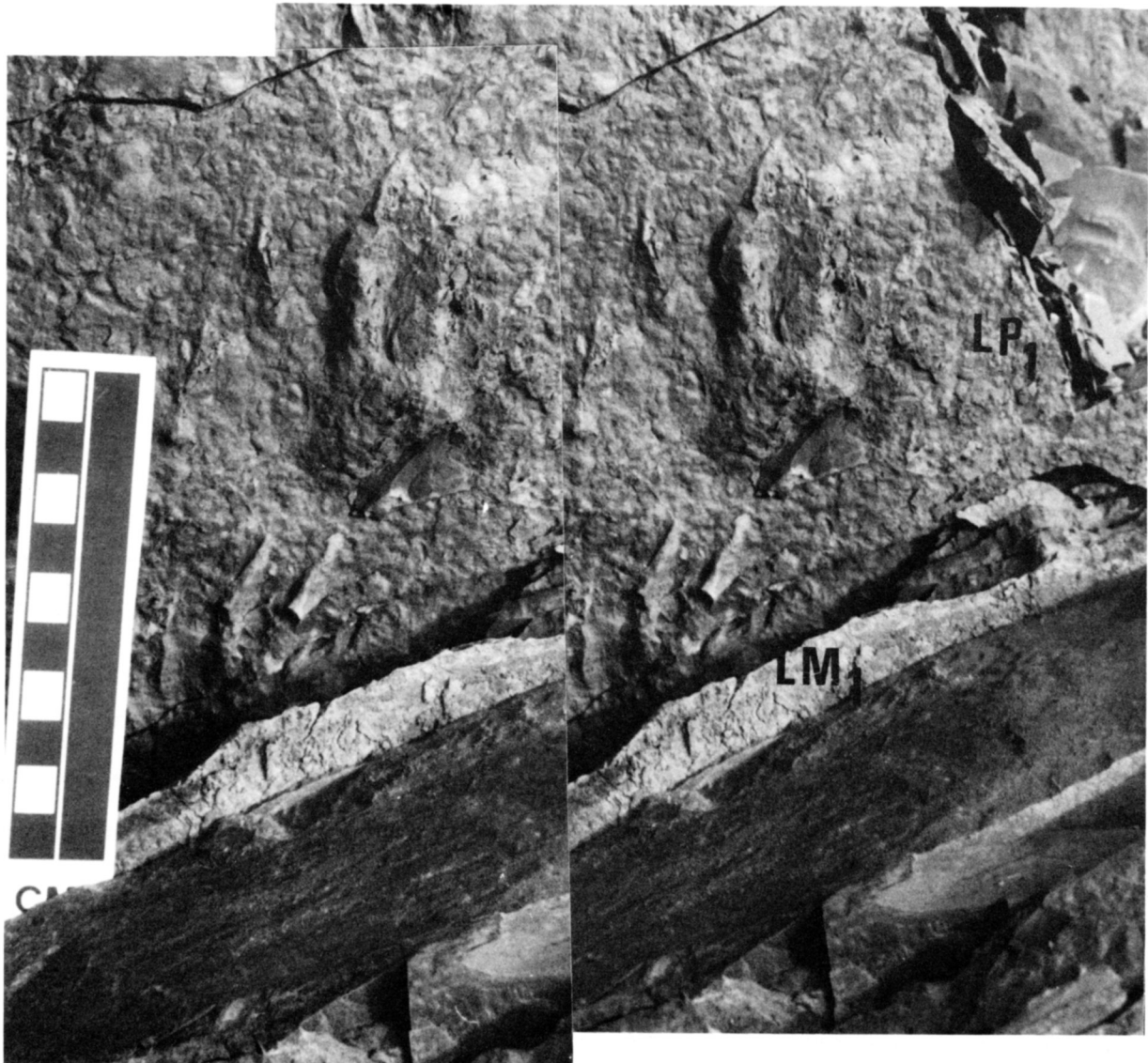
Dimensions: The footprints of trackway #1 are not equally well-impressed. Those on the left hand side of the trackway are much less clearly impressed than those on the right. The trackway comes very close to what Peabody (1959) termed "primary couplings", i.e., the hind-footprints have almost totally obliterated the fore-footprints. According to Haubold (1971, p. 27), this feature, together with the slow gait evident in trackway #1 (Figs. 5 and 6), is characteristic of *Pseudobradypus*. Further features include plantigrade pentadactyl footprint impressions of manus and pes. Detailed comparisons between holotype and figured specimens are shown in Table 1. Although poor preservation and overlapping conditions of manus and pes do not facilitate comparisons, there is nevertheless good general resemblance between holotype and figured specimens although the former is more than twice as large as the latter.

Measurements given in Table 1 for the Rams Head

specimen are based on the best impressions in trackway #1, specifically the average for RP₂, RP₃ and RP₃. These should be compared with measurements of footprints (LM₁, LP₂) of specimen b in trackway #4 (see Fig. 7). Trackway #4 was created by a slightly smaller individual than that which made trackway #1 (see Table 2). Apart from differences in creature size, the contrast in stride, pace, step angle and absence of primary coupling in trackway #1 are directly attributable to the relatively drier and possibly firmer ground in which trackway #4 was created. It should be noted that in view of the different sizes of the individual trackmakers, and the different ground conditions, these types of measurements are highly subjective.

Remarks: The holotype, from the Westphalian A, Saarland, is housed in the Geologisches Museum der Saarbergwerke, Germany. Trackway #1 exhibits a curiously asymmetrical body drag with respect to the footprints. Possible explanations include: injury; passage of the animal along an inclined surface (shoreline or stream bank); modification by erosion of an originally symmetrical body drag; efforts of the animal to turn from a straight path. The latter is the favoured explanation. An excellent illustration of the phenomenon is seen to advantage in a longer trackway figured by Mossman

a)



b)

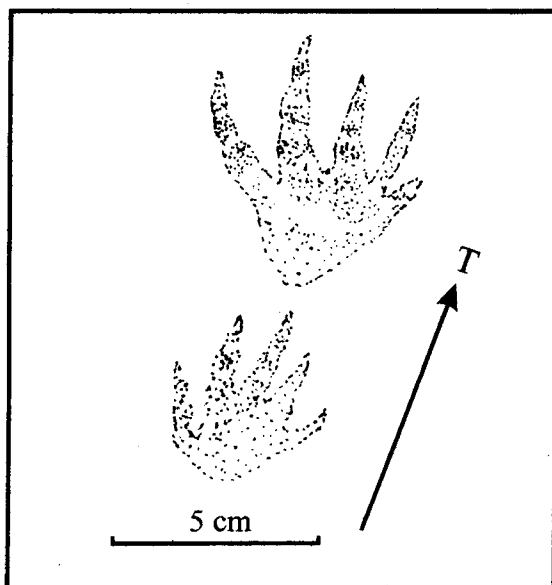


Fig. 7. a) Stereographic photographs of pair of footprints (LM_1 , LP_1) of *Pseudobradypus erneri* from trackway #4 (LM_1 was only partially recovered). b) Interpretive sketch of *Pseudobradypus erneri* in trackway #4 from two of the better preserved pes (LP_1 and LP_2) and a combination of several partially preserved mani impressions including LM_1 ; T shows the trackway direction, which intersects trackway #1 at about 20° . Scale bar = 5 cm. Photograph by D. Mossman.

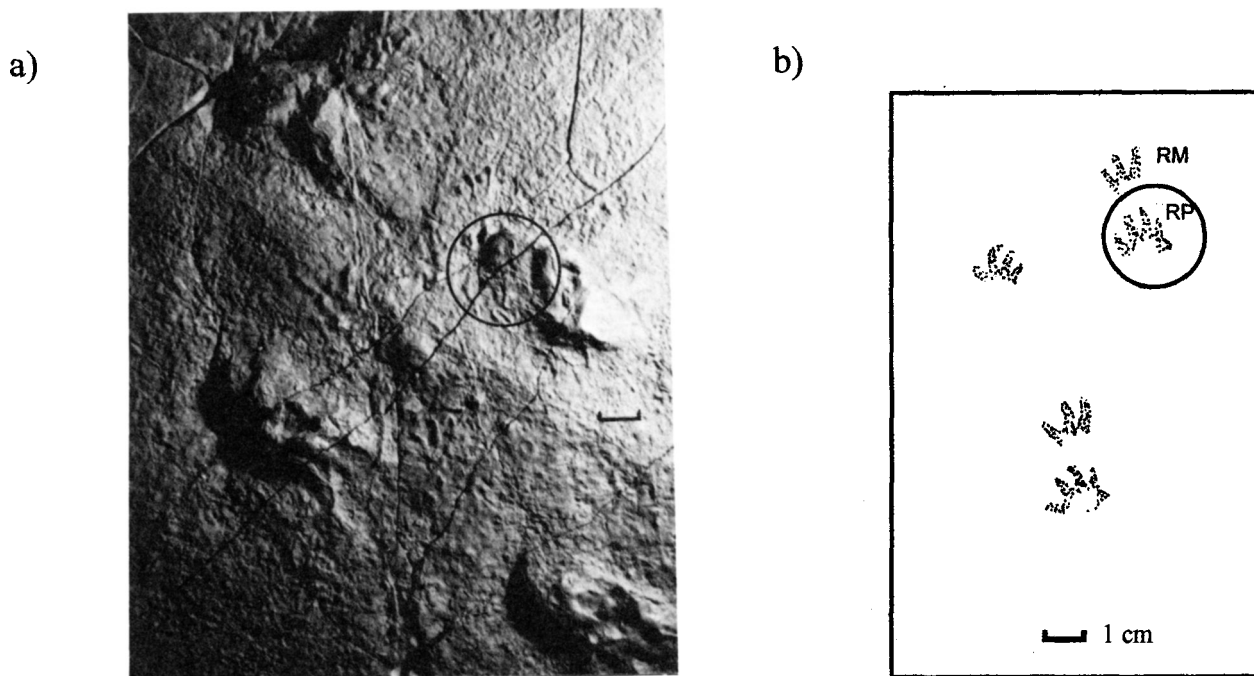


Fig. 8. a) A portion of trackway #5, *Hylopus hardingi*. Circle shows partially preserved impressions of three of one pair of a total of 11 poorly preserved successive pairs of footprints. Note that the RP (in circle) overprints earlier footprint(s) of *Pseudobradypus ernereri*. Scale bar = 1 cm. b) Interpretive sketch of *Hylopus hardingi* footprints. Scale bar = 1 cm. Photograph by D. Mossman.

and Place (1989, fig. 3, p. 593) from Permian strata on Prince Edward Island.

Trackways 2 and 3 are believed to have been made by trackmakers similar to those that made trackways #1 and #4. Unfortunately, however, they provide inadequate details to confirm ichnospecific assignment. The producer of trackway #2 seems to have been the largest of all four. Trackways #2 and #3 each extend just over one meter (right to left) in a direction opposite to that of the creature that made trackway #1. The producer of trackway #2 needed to propel itself (cf. Peabody 1959, plate 5E, p. 59) by pushing with its tail (arrow in Fig. 2 shows pressure ridges, i.e., build-up of material), indicating water-saturated ground conditions, or possibly very shallow water conditions at the time of passage. The somewhat smaller (judging by footprint size and trackway width) creature that made trackway #3 may have had an easier passage between the seed fern stalks dotting the local landscape. With a short stride and low step angle, it left behind no less than 15 successive footprint impressions. Overall, despite its apparently inefficient walking mode, the trackway appears more reptilian than amphibian, an interpretation confirmed by the evidence of claws, and on specimen b the presence of phalangeal pads (see Fig. 7). The relatively clear impressions of this specimen bodes well for the possible future discoveries of a well-preserved ichnofauna in this area. Although recorded widely throughout Europe (Haubold 1974; 1984) *Pseudobradypus ernereri* is limited to the Westphalian A stage of the Carboniferous (Schmidt 1963). This is its first reported occurrence in Nova Scotia.

Class: Amphibia
Subclass: Lepospondylia Zittel, 1887
Order: Temnospondylia Zittel, 1887
Superfamilia: Edopsoidea Romer, 1945 or Eryopoidea Romer, 1945
Ichnospecies: *Hylopus hardingi* Dawson, 1882
(Fig. 8, Table 2)

Description: Quadrupedal trackway showing 11 poorly preserved sets of footprints, manus tetradactyl, slightly smaller than pes; both plantigrade. Pes pentadactyl. Digits of manus and pes well-impressed in several cases, palms and soles less commonly so. Fine details are lacking even on the two best preserved (right hand) sets of footprints (Fig. 8). The trackway appears to overprint the earlier formed much larger reptilian footprints (specifically RP₃ and RM₃) of *Pseudobradypus ernereri*.

Dimensions: Unfortunately, preservation of these footprints, like many others on this slab of fine-grained sandstone, is not good. The measurements given in Table 2 are based specifically on the average of two sets of footprints (RM₅, RP₅ and RM₆, RP₆). Maximum length of the footprints is given from back of palm imprint to the tip of digit IV. The maximum width (span) is given from the tip of digit 1 to the tip of digit V (Table 1). Interdigital span is approximately 110°.

Remarks: These footprints are smaller, but correspond in general to those of the type *Hylopus hardingi* as originally figured by Matthew (1904) (in Sarjeant and Mossman 1978, p. 287). Isolated remnants of individual or of discrete pairs of

Table 2. Comparison of measurements of footprints of the type *Hylopus hardingi* Dawson from Joggins (after Matthew 1904) and the figured specimens from Rams Head.

	Type	Paratype
Stride (mm)	91	150
Width of trackway (centre to centre in mm)	62	120
Manus length (mm)	22	27
Manus width (mm)	30	ca. 33
Pes length (mm)	28	34
Pes width (mm)	33	39
Total interdigital span (degrees)	85 (RM)	—
Step angle (degrees)	100 (RP)	ca. 100

footprints occur elsewhere on this same bedding plane surface (e.g., sample FGM 999Gf. M6 - K6).

MICROSAURIAN FOOTPRINTS

Two other ichnospecies are represented in convex hyporelief on the principal bedding plane. One is *Dromillopus quadrifidus* Matthew, 1905 as recently redescribed (Mossman and Grantham 1996), which is present as several isolated footprints (e.g., sample FGM 999Gf, 12 JG. 2). Another, *Cursipes dawsoni* Matthew, 1903 is represented by a single well-preserved pes impression and several accompanying indistinctly defined impressions (sample FGM 999Gf, 12 C1 - B1).

DISCUSSION AND CONCLUSIONS

The ichnofauna preserved in upper Carboniferous red beds at Rams Head contains early amphibian and reptilian ichnofossils that substantiate the interpretations (Belt 1965; Ryan *et al.* 1991; Naylor and Kennedy 1997) regarding the age and the origin of the Parrsboro Formation.

Naylor and Kennedy (1997, p. 120) noted, "The red colour, fossil roots and calcrete nodules suggest a floodplain environment that had a low water table that favoured the development of plants and soils". To this description the occurrence of trace fossils indicating abundant animal life must be added. The ichnofauna preserved in upper Carboniferous red beds at Rams Head contains the remains of creatures that thrived under warm and moist conditions within vegetated regions of a floodplain subjected to fluctuating water levels. These are properly terms an "ichnocoenose", an assemblage from a single level of trace fossils representing the activities of an association of living organisms (Casamiquela *et al.* 1987, p. 43). There are strong indications that, as erosion proceeds, further exposure of this level holds good potential for adding to this ichnocoenose (Naylor and Kennedy 1997; McCarthy 1999). This is perhaps only to be expected given that the Joggins (Coal Mine Point Member) and Boss Point formations are in part coeval with the Parrsboro Formation. Neither should it prove surprising to discover further

ichnotaxa here, such as are known in equivalent Pangean strata (e.g., lower Bochum) in parts of Europe.

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