A probable thyreophoran (Dinosauria, Ornithischia) footprint from the Upper Triassic of southern Sweden

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A curious blunt-toed tridactyl footprint of a relatively large trackmaker is stored in the Geological Museum in Copenhagen. The footprint was found nearly 50 years ago in the Rhaetian coal-bearing strata mined in the Gustav Adolf Mine, near Höganäs, Scania, Southern Sweden. The morphology of the specimen suggests that it was left by an early advanced thyreophoran dinosaur, in this case the earliest known.

Key-words: Footprint, Thyreophoran dinosaur, Late Triassic, Scania, Sweden.

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Dinosaur footprints from the Upper Triassic, Rhaetian, Höganäs Formation, in southern Sweden were first reported by Bölau (1952), who described them as theropod footprints without assigning them to any ichnotaxon. Other tracks, also of theropod origin, were found in the Early Jurassic strata of Helsingborg and Valläkra (Pleijel 1975; Ahlberg & Siverson 1991). Gierlinski & Ahlberg (1994) assigned Late Triassic tracks from southern Sweden to the ichnotaxon *Grallator (Eubrontes) giganteus* Hitchcock, 1845, and the Lower Jurassic tracks to *Grallator (Eubrontes) soltykovensis* Gierlinski, 1991 following subichnogeneric designation proposed by Olsen and Galton (1984). Recently, these ichnotaxa have been revised as *Eubrontes giganteus* and *Kayentapus soltykovensis* (see Gierlinski 1996; Olsen *et al*. 1998). All tracks so far described from the Höganäs Formation have been clearly of theropod origin, characterized by a functionally tridactyl pes, the third digit being the longest, and having relatively narrow claws (Fig. 1). However, the specimen exhibited on display at the Geological Museum in Copenhagen (MGUH 27219) (Fig. 2), differs from all other Early Mesozoic tracks hitherto described from southern Sweden. The track was found in the roof of the Gustav Adolf coal mine, Höganäs, between 1950 and 1955 and was purchased by the Geological Museum in Copenhagen from a relative to one of the workers from the mine. Vertebrate tracks are often found in

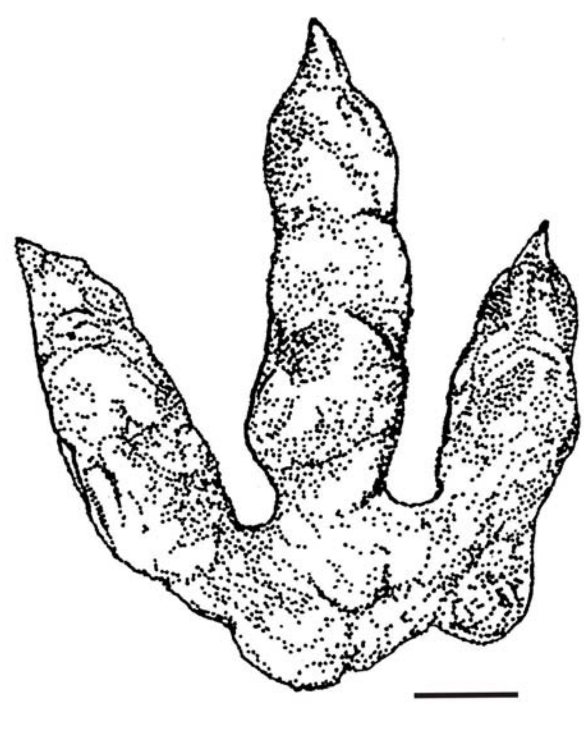

Fig. 1. Typical theropod track, *Grallator (Eubrontes) giganteus* from the Gustaf Adolf coal mine in Höganäs, southern Sweden. Notice the long slender digit impressions and the sharp laterally compressed claw imprints. Scalebar 5 cm. Figure modified after Gierlinski & Ahlberg 1994.

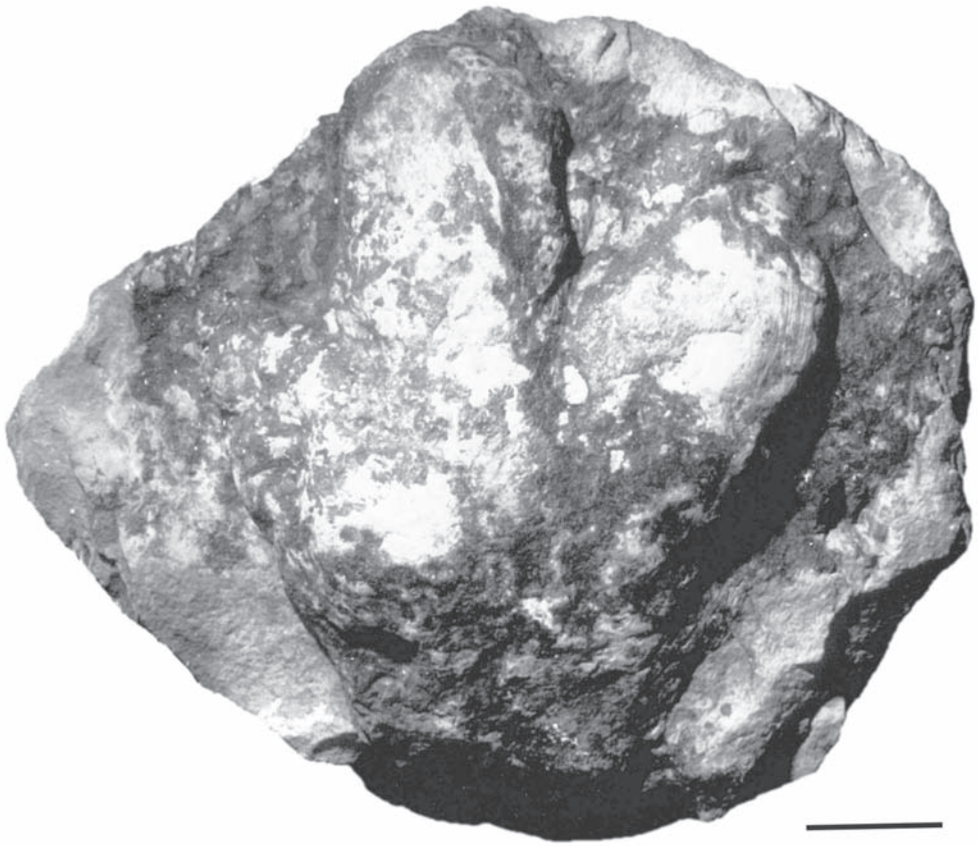

Fig. 2. The probable ornithischian footprint (MGUH 27219), from the Bjuv Member mined in the Gustav Adolf Mine in Scania, Sweden. Scale bar is 5 cm. Photo Ole Bang Berthelsen.

the roofs of coal mines, because the techniques used in mining exposes large surfaces at lithological boundaries, which are ideal for track preservation and recognition (Parker & Balsley 1989; Parker & Rowley 1989). In the Gustav Adolf mine, the Rhaetian Bjuv Member of the Höganäs Formation was mined. According to the Geological Museum, Copenhagen, the specimen was found together with three other footprints, presumably forming a short trackway, but a recent attempt to locate the storage of the other three ichnites from the presumed trackway was unsuccessful.

Footprint description

The footprint (Fig. 2) is preserved as a natural cast filled with sandy heterolithic siltstone. Parts of the track are still covered with a thin layer of coal originating from the coal-seam in which it was originally impressed.

The track is tridactyl with short, blunt digits, which are subequal in length. The shapes of the digit impressions are well defined, forming steep to vertical trackwalls sensu Brown (1999) in the middle digit impression and vertical trackwalls in parts of the left digit. A now repaired fracture running through the slab has caused the loss of the distal end of the right digit. Faint colour variation in the surface of the slab indicates the approximate extend of the missing digit (Fig. 3).

The footprint is 26 cm long, measured from the tip of the middle digit to the proximal edge of the metatarsal-phalangeal area. The width of the track is 28.5 cm; including the estimated extent of the missing part of the left digit. The track is uniformly impressed to a depth of 3–3.5 cm. The digit impressions become shallower in the distal parts and the metatarsal area uniformly slopes down to the level of the original sediment surface during the proximal 7 cm of the track. The faint contour of a distal phalangeal pad and the possible trace of a short, wide claw, are preserved in the impression of the right digit. The divarication angle between the two outer digits equals 76°.

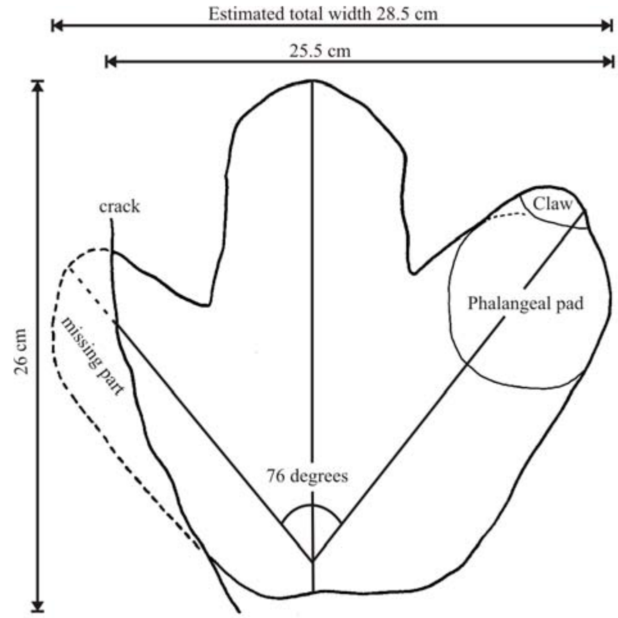

Fig. Interpretative drawing of the specimen with measurements given.

Discussion

The morphology of the Copenhagen specimen clearly differs from the grallatorid footprints hitherto reported from Höganäs Formation. Theropod tracks in general are characterized by being longer than wide, and having long, slender digits terminating in sharp claw impressions (Lockley 1991). The Copenhagen specimen has short, broad and blunt-ended digits, and the track is broader than long. Such morphology is more consistent with the footprints of large ornithopods from the Cretaceous, than those known from the Jurassic. Among the Jurassic forms there are only few, relatively rare exceptions, which correspond with the discussed specimen. Those exceptions represent supposedly Stegosaurian footprints from the Late Jurassic, Oxfordian (Gierlinski & Sabath 2002) and the Early Jurassic, Upper Hettangian, ichnotaxon of *Moyenisauropus karaszevskii* Gierlinski, 1991, which was proposed to be of proto-stegosaurian origin (Le Loeuff *et al*. 1999; Gierlinski 1999).

One possible explanation that should be considered for the ornithischian-like shape of this footprint is that it is an undertrack. Undertracks form when an animal left tracks in layered sediments. In that case the weight of the animal's foot not only forms a track on the trampled surface, i.e. the tracking surface, but the layers subjacent to the tracking surface are also subject to deformation. Experimental work with track

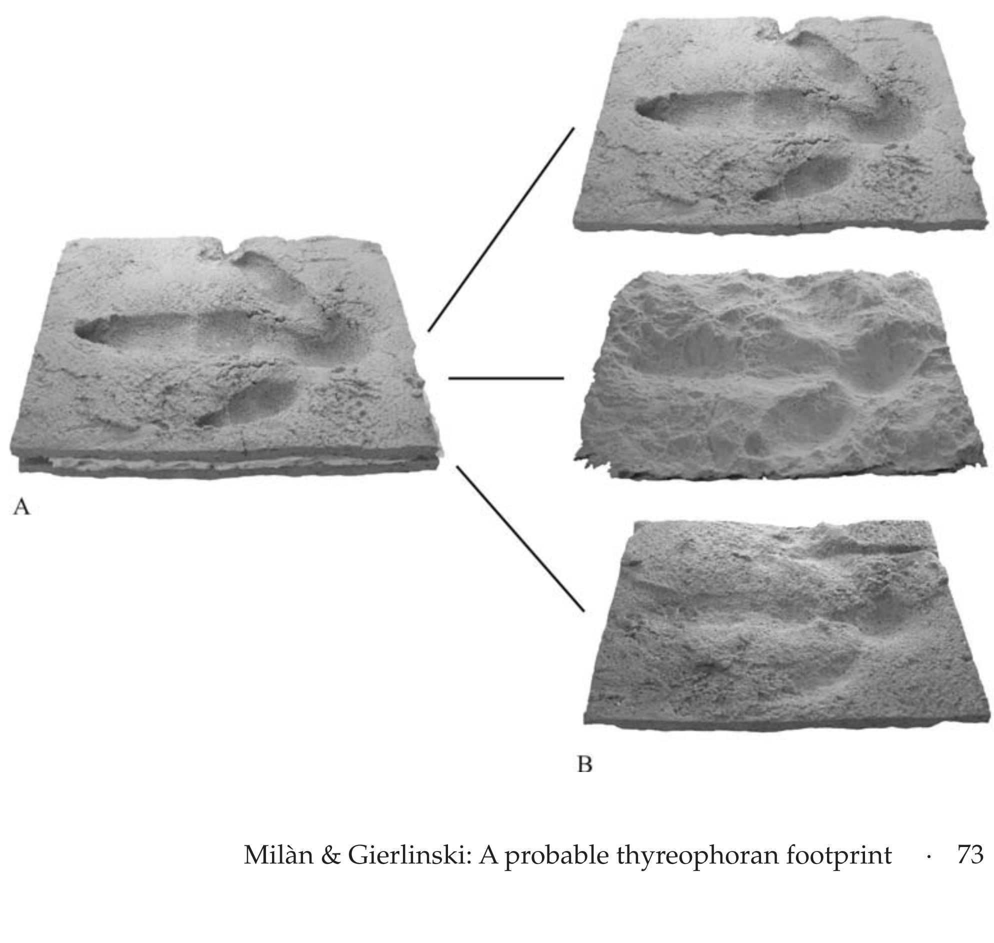

Fig. 4. Formation of undertracks demonstrated with an emu (*Dromaius novaehollandiae*) footprint formed in a layered package of artificial sediments. A, a track formed in layered sediment not only leaves an impression on the trampled surface, but the subjacent layers are also subject to deformation. When the layered package is split horizontally, B, an impression of the track can be found on the subjacent horizons, each undertrack being shallower, more rounded, and less detailed downward. The length of the true track is 19.5 cm. Figure modified from Milàn & Bromley (in press).

formation in artificial substates (Milan & Bromley 2003, in press), demonstrate how the morphology of undertracks differs from that of true tracks, in that the digit impressions become shallower, wider, more rounded and preserve fewer anatomical details, for each successive layer downward (see Fig. 4).

The broad, rounded digits in the track discussed do have a superficial undertrack-like appearance. However, the presence of steep to vertical trackwalls in parts of the track makes the undertrack hypothesis unlikely. Undertracks will have sloping trackwalls without the well-defined edges between the tracking surface and the track as present in the Copenhagen specimen.

In conclusion the track is a true track, unaltered by pen contemporaneous erosion. The morphology of the track, being broader than long, with short, broad digits is consistent with that of supposed thyreophoran tracks from the Early Jurassic of Poland. Thus, the Late Triassic age of the described footprint suggests that the track represents the hitherto oldest known footprint of a large thyreophoran dinosaur.

Danish Summary

Et bemærkelsesværdigt fossilt dinosaur fodspor fra Øvre Trias, udstillet på Geologisk Musum, København har vist sig at være en hidtil ukendt form. Sporet blev fundet i loftet af Gustaf Adolf kulminen ved Höganäs omkring 1950–55. Alle hidtil beskrevne dinosaur fodspor fra det skånske område stammer fra rovdinosaurere. Rovdinosaur spor (Fig. 1) er karakteristisk ved at de tretåede, har aftryk af lange slanke tæer med skarpe kløer, samt at den midterste tå er betydelig længere end de to ydre tæer, hvilket gør sporet længere end det er bredt. Det heri beskrevne spor (Fig. 2) afviger fra denne morfologi i at være bredere end det er langt at og have korte, tykke, afrundede tæer. Denne spormorfologi er fundet i spor fra panserøgler, Thyreophora, fra nedre Jura i Polen. Den øvre Triassiske alder af det heri beskrevne spor, tyder på at sporet repræsenter det hidtil ældste kendte spor fra en pansret dinosaur.

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