A second specimen of *Blikanasaurus* (Dinosauria: Sauropoda) and the biostratigraphy of the lower Elliot Formation

Adam M. Yates
Bernard Price Institute for Palaeontological Research, School of Geosciences, University of the Witwatersrand, Private Bag 3, WITS, 2050 South Africa
E-mail: yatesam@gmail.com

Received 25 September 2007. Accepted 29 January 2008

A second specimen of the rare basal sauropod *Blikanasaurus cromptoni,* is recorded from a site in the Ladybrand district of the Eastern Free State, South Africa. The specimen consists of a right metatarsal 1 that originated from the upper 20 m of the lower Elliot Formation. It can be referred to *B. cromptoni* on the basis of its small size and highly robust proportions, which distinguish this taxon from all other sauropodomorphs. This record extends the geographic distribution of *B. cromptoni* north into the region of the main Karoo Basin where the Elliot Formation is dramatically thinner. It also extends the known stratigraphic range of *B. cromptoni* up from the base of the Elliot Formation into a position near the top of the lower member. This new record, combined with other new discoveries, supports the hypothesis that the thin northern part of the lower Elliot Formation is a condensed section that is largely, if not entirely, coeval with the thicker southern sections.

Keywords: basal sauropod, *Blikanasaurus,* Triassic, biostratigraphy, Karoo Basin, Elliot Formation.

INTRODUCTION

The dinosaur-rich Elliot Formation was deposited during the latest stages of filling of the main Karoo Basin, a large foreland basin to the north of the Cape Fold Belt in southern Africa. The northern third of the basin overlies the Kaapvaal Craton, which is an ancient continental block that influenced the tectonic development of the Karoo Basin during the deposition of the Elliot Formation. As a result the thickness of the Elliot Formation dramatically increases south of the Craton (Bordy *et al.* 2004). The difference in thickness on and off the Craton is particularly strongly marked in the lower part of the Elliot Formation, which is thought to be Late Triassic in age (Olsen & Galton 1984; Lucas & Hancox 2001). It is not known whether the greater thickness in the south represents an expanded section that is coeval with northern sections or whether a greater time span of deposition is represented in the south and no research has been directed towards this question. Until recently the latter hypothesis would have appeared more likely given that there was a set of taxa, including the cynodont *Scalenodontoides macrodontes* and the dinosaurs *Aliwalia rex* and *Blikanasaurus cromptoni,* which had only been found in the southern end of the basin and were apparently restricted to the lowermost part of the lower Elliot Formation (Gow & Hancox 1993; Galton & Van Heerden 1998).

Blikanasaurus cromptoni is a basal sauropod dinosaur (Yates & Kitching 2003; Galton & Upchurch 2004) that was first described as belonging to a new, monotypic family of prosauropods (Galton & van Heerden 1985). Until now this species was known from a single specimen found in the 'passage beds' of Blikana Mountain in the Herschel District (Charig *et al.* 1965), at the southern end of the exposure of the Elliot Formation (Fig. 1). The so-called Passage Beds were named for the beds that are 'lithologically transitional between the typical Molteno Beds below and the typical Red Beds [= Elliot Formation] above' (Charig *et al.* 1965, p. 200). This echoed the thought of several geologists claimed that the Molteno-Elliot contact was conformable and gradational (Du Toit 1939; Turner 1972; Eriksson 1984). However, it is now apparent that there is a regional disconformity between these two formations (Bordy *et al.* 2005). Bone preservation has never been observed in the Molteno Formation below the level of this disconformity (Turner 1972; Bordy *et al.* 2005). Thus it is almost certain that the holotype of *B. cromptoni* originated from the lowest part of the lower Elliot Formation, above the disconformity. This paper records the second known specimen of *B. cromptoni* and demonstrates both its presence in the northern part of the basin and in a stratigraphic position well above the base of the lower Elliot Formation. The stratigraphic range and geographic distribution of other lower Elliot amniotes are also examined and their implications for biostratigraphy and basin development are discussed.

MATERIALS

BP/1/5271 is a group lot of bones that were collected by J.W. Kitching in 1984 and contains a number of sauropodomorph postcranial pieces. Included amongst these is a small, robust right metatarsal I that is identified here as the second known specimen of *B. cromptoni.* The collection appears to be gathering of surface float and there is no indication they represent a single associated individual. The size disparity represented by these elements indicates that more than one individual and possibly taxon is represented. Given the lack of definitive association the metatarsal in question has been designated as BP/1/5271a.

LOCALITY AND HORIZON

The various elements of BP/1/5271 were collected from the lower Elliot Formation outcropping in a large erosional

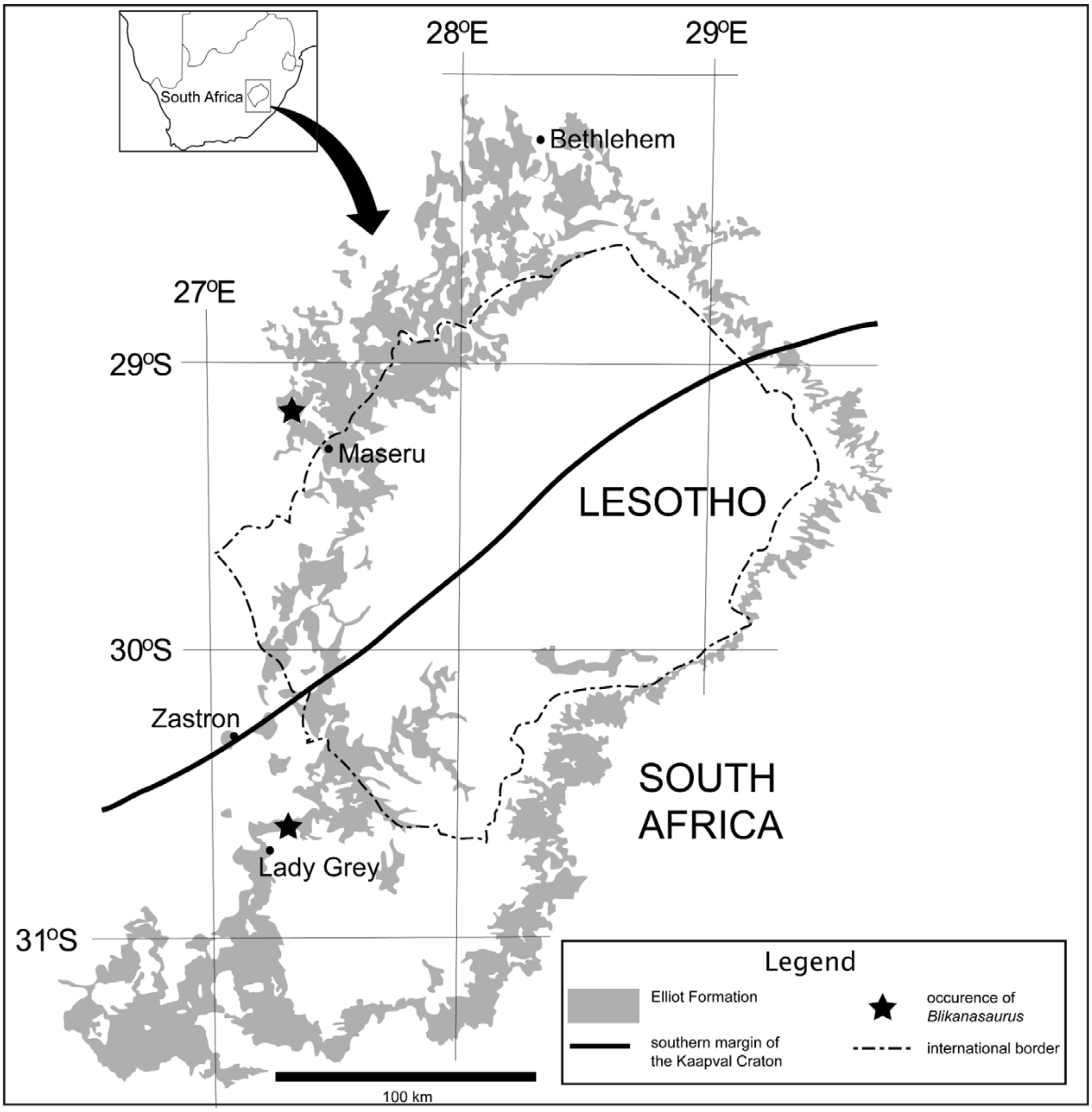

Figure 1. Map of the exposure of the Elliot Formation in the main Karoo Basin of South Africa and Lesotho showing the two known localities of *Blikanasaurus* both on and off the Kaapvaal Craton. Redrawn from Bordy *et al.* (2004).

gully ('donga') on the farm Damplaats in the Ladybrand District of the Eastern Free State. This is the same erosional gully that produced the only known articulated skeleton and skull of *Melanorosaurus readi* (Welman 1999; Yates 2007a; Bonnan & Yates 2007) and the holotype of *Eocursor parvus* (Butler *et al.* 2007). The Ladybrand district is underlain by the Kaapvaal Craton where the lower Elliot Formation is quite thin. Stratigraphic examination of Damplaats places the strata exposed in the donga below the disconformity that separates the upper (Jurassic) and lower (Triassic) units of the Elliot Formation (Butler *et al.* 2007, supplementary material, fig. S1). Complete sections of the lower Elliot Formation in the Ladybrand district are about 60 m in total thickness (Smith & Kitching 1997; Bordy *et al.* 2004) but only the upper 20 m of the Elliot Formation is present at Damplaats (roughly the upper 30% of the unit). Although the precise stratigraphic location of the specimens in BP/1/5271 is not recorded they can only have come from near the top of the lower Elliot Formation because that is all that is exposed at the collection site.

COMPARISON WITH OTHER SAUROPODOMORPHS

The morphology of the distal articular surface clearly identifies BP/1/5271a as a sauropodomorph. The transverse axis of this surface is angled distolaterally, which is a characteristic of Sauropodomorpha more derived than *Saturnalia* (Yates 2007a: character 333). Furthermore the medial distal condyle is highly reduced relative to the lateral distal condyle, while a distinct flexor notch separating the two is maintained. This characteristic is widespread amongst basal sauropodomorphs and basal sauropods and also appears to be diagnostic of Sauropodomorpha more derived than *Saturnalia*, although the character has yet to be used in a cladistic analysis.

An explanation of the phylogenetic taxonomy used in this paper is required before this discussion can proceed.

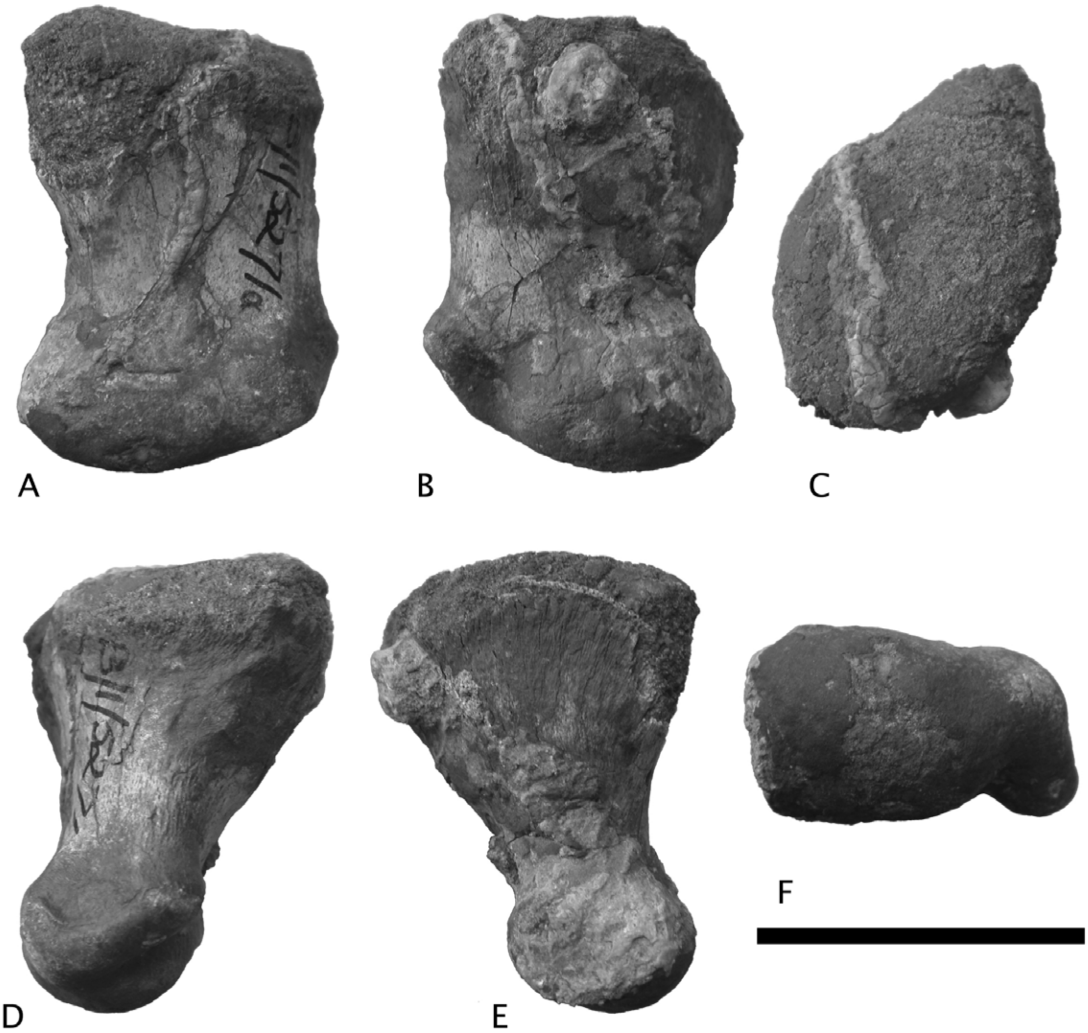

Figure 2. Right metatarsal I of *Blikanasaurus cromptoni* (BP/1/5271a) in (**A**) extensor, (**B**) flexor, (**C**) medial, (**D**) lateral, (**E**) proximal and (**F**) distal views. Scale bar = 50 mm.

A number of definitions of Sauropoda have been proposed over the past decade. The earliest of these is that it is the most inclusive clade including *Saltasaurus loricatus* (a derived Cretaceous neosauropod) but not the familiar 'prosauropod' *Plateosaurus engelhardti* (Wilson & Sereno 1998). However this definition includes numerous traditional 'prosauropods' when applied to phylogenies where basal sauropodomorphs are strongly paraphyletic. Thus the definition of Yates (2007b) is used here. Under this definition Sauropoda is the most inclusive clade including *Saltasaurus loricatus* but not *Melanorosaurus readi* and includes the relatively large obligatory quadrupedal forms and excludes nearly all forms that had traditionally been included in Prosauropoda (with *Blikanasaurus cromptoni* being a notable exception) in all currently viable hypotheses of basal sauropodomorph relationships.

BP/1/5271a is a remarkably robust element in extensor view (the midshaft width is 55% of the total length of the bone) suggesting a position among basal sauropods. The midshaft width is less than half the total length of metatarsal I, in non-sauropod sauropodomorphs, for example it is 40.6 in *Jingshanosaurus xinwaensis* (LV 3), 21% in *Anchisaurus polyzelus* (YPM 208), and 24% in *Lufengosaurus huenei* (Young 1941, fig. 25). Amongst the sauropodomorphs from the lower Elliot Formation similarly stout first metatarsals are found only in the basal sauropods *Antetonitrus ingenipes* (BP/1/4952: 54%) and *Blikanasaurus cromptoni* (SAM-PK-K 403: 53%). The near-sauropod *Melanorosaurus readi* is also somewhat stout-footed but the proportions of its first metatarsal lie firmly in the range of more basal sauropodomorphs (NM 1551: 39%). Although the first metatarsals of the other lower Elliot sauropodomorphs (*Eucnemesaurus fortis*, *Plateosauravus cullingworthi* and an unnamed taxon from the farm Nova Barletta in the Clocolan district) are currently unknown it is very unlikely that they had stout, sauropod-like metatarsals, like BP/1/5271a, given that their phylogenetic position is basal to the advanced stout-footed forms (Yates 2003, 2007a).

The Damplaats metatarsal differs from *Antetonitrus ingenipes* and shares the following derived similarities with the holotype of *Blikanasaurus cromptoni.* Firstly, the size of BP/1/5271a is close to that of SAM-PK-K 403 and is much smaller than *Antetonitrus ingenipes* (Table 1). A study of the evolution of size in Sauropodomorpha indicates that the small size of *Blikanasaurus cromptoni* is an autapomorphic reversal of the trend towards increased size in the sauropod lineage (Yates 2004). Secondly, the extensor-flexor depth of the distal articular surface is greater relative to the transverse width of the articular

Table 1. Measurements of the first metatarsal of various basal sauropods including BP/1/5271a. All measurements are in mm.

Measurement	*Melanorosaurus* NM 1551	*Antetonitrus* BP/1/4952	*Blikanasaurus* BP/1/5271a	*Blikanasaurus* SAM-PK-K 403
Length	119	120	70	86
Minimum transverse shaft width	47	63	36.5	41
Maximum width of proximal articular surface	69	93.5	56.4	76.5
Width orthogonal to max. prox. width	33	59	36.5	36.5
Transverse width of distal articular surface	67	88.6	46	54
Extensor-Flexor depth of distal articular surface	37	43.7	26	38
Minimum extensor-flexor depth of shaft	23	31.3	21	31

surface in BP/1/5271a (72%) and the holotype of *Blikanasaurus cromptoni* (SAM-PK-K 403: 70%) than in *Antetonitrus ingenipes* (BP/1/4952: 49%). Thirdly, the minimum extensor-flexor depth of the shaft is relatively greater in BP/1/4952 (30%) and SAM-PK-K 403 (36%) than in *Antetonitrus ingenipes* (26%). Based on these comparisons the element can be identified as belonging to *Blikanasaurus cromptoni.*

DISCUSSION

Prior to 2006 there was a small set of amniote taxa that were only known from the lowest beds of the lower Elliot Formation from the south end of the basin where this unit reaches on average 300 metres in thickness (Bordy *et al.* 2004). These included the cynodont *Scalenodontoides macrodontes* and the dinosaurs *Aliwalia rex* and *Blikanasaurus cromptoni. Scalenodontoides* was known from a number of specimens that all derived from the lowest beds of the lower Elliot Formation (Gow & Hancox 1993). As discussed above, the type locality of *Blikanasaurus cromptoni* is located at the very base of the lower Elliot Formation while that of *Aliwalia rex* is recorded as ‘Barnard’s Spruit (= creek), Ward, 15 miles south of Aliwal North’ (Seeley, 1894, p. 317, quoted in Galton & van Heerden 1998, p. 175). No record of ‘Ward’ as a place-name in the Aliwal North district could be found although Barnard’s Spruit is present in the area. Kitching & Raath (1984) note that the directions would place the locality on the farm Ezelsklip. On this farm the creek is deeply incised into the ‘Stormberg group’ so that if the site is located near the banks of the creek on this farm then it would have to be low in the lower Elliot Formation close to the contact with the Molteno Formation (3026 Aliwal North, 1:250 000 geological map series).

These three taxa hinted at the possibility of a distinct faunal assemblage that preceded the typical fauna of the lower Elliot Formation (usually attributed to the ‘*Euskelosaurus* Range Zone’ [Kitching & Raath 1984]) that was only deposited in the south. However, a skull of *Scalenodontoides macrodontes* has recently been identified that was collected from a site in Lesotho near the northern limit of the Elliot Formation (Battail 2006). Similarly the two dinosaur taxa are now known to occur in sections that lie on the Kaapvaal Craton. *Aliwalia rex* has been recognized as a junior synonym of *Eucnemesaurus fortis,* which is known from two sites at the northern end of the basin: Zonderhout in the Fouriesburg District and Spion Kop in the Senekal District (Yates 2007b). Furthermore the *Eucnemesaurus fortis* collected from Spion Kop was found just over 30 metres above the base of the Elliot Formation, from a site approximately half way up the lower member (recorded as the third vertebrate fossil occurrence from the base in Yates *et al.* 2004, fig. 2). As discussed above the new *Blikanasaurus cromptoni* specimen is also from the northern end of the basin and from a stratigraphic position at least 30 metres above the base of the lower Elliot Formation.

Thus there is currently no evidence for a distinct, early biostratigraphic assemblage that is only present at the south end of the basin. Furthermore the fauna of the lower Elliot Formation would appear to be homogenous for most of its thickness and geographic extent. This suggests that the thinner northern section is a condensed section that is coeval with the southern section. Thus the onset of deposition of the Elliot Formation appears to have been more or less synchronous on and off the Kaapvaal Craton (at least at the level of resolution afforded by vertebrate biostratigraphy). However, it is necessary to collect more diagnostic specimens that are well placed stratigraphically before any sort of biostratigraphic subdivision of the lower Elliot Formation can be ruled out.

For access to specimens in their care that are cited in this paper I thank R. Smith and S. Kaal (South African Museum), J. Botha and E. Butler (National Museum), L. Murray and D. Brinkman (Yale Peabody Museum). Ji Xueping facilitated my visit to Yunnan and obtained the necessary permissions. B. Rubidge read an earlier draft of the manuscript and offered helpful suggestions. Travel to China was funded by PAST while travel to Cape Town was funded by the NRF.

INSTITUTIONAL ABBREVIATIONS

BP	Bernard Price Institute for Palaeontological Research, University of the Witwatersrand, Johannesburg.
LV	Museum of Lufeng Dinosaurs, Jingshan.
NM	National Museum, Bloemfontein.
SAM	Iziko South African Museum, Cape Town.
YPM	Peabody Museum of Natural History, Yale University, New Haven.

REFERENCES.

BATTAIL, B. 2006 (for 2005). Late Triassic traversodontids (Synapsida: Cynodontia) in southern Africa. *Palaeontologia africana* **41**, 67–80

BONNAN, M.F. & A.M. YATES. 2007. A new description of the forelimb of the basal sauropodomorph *Melanorosaurus*: implications for the evolution of pronation, manus shape and quadrupedalism in sauropod dinosaurs. **In**: Barrett, P.M. and Batten, D.J. (eds), *Evolution and Palaeobiology of Early Sauropodomorph Dinosaurs. Special Papers in Palaeontology* **77**, 157–168.

BORDY, E.M., HANCOX, P.J. & RUBIDGE, B.S. 2004. Basin development during the deposition of the Elliot Formation (Late Triassic–Early Jurassic), Karoo Supergroup, South Africa. *South African Journal of Geology* **107**, 395–410.

BORDY, E.M., HANCOX, P.J. & RUBIDGE, B.S. 2005. The contact of the Molteno and Elliot Formations through the main Karoo Basin, South

Africa: a second order sequence boundary. *South African Journal of Geology* **108**, 351–364.

BUTLER, R.J., SMITH, R. M. H. & NORMAN, D.B. 2007. A new primitive ornithischian dinosaur from the Late Triassic of South Africa. *Proceedings of the Royal Society of London, Series B,* **274,** 2041–2048. doi: 10.1098/rspb.2007.0367.

CHARIG, A.J., ATTRIDGE, J. & CROMPTON, A.W. 1965. On the origin of the sauropods and the classification of the Saurischia. *Proceedings of the Linnean Society* **176**, 197–221.

DU TOIT, A. 1939. *Geology of South Africa* (2nd edn). Edinburgh, Oliver and Boyd.

ERIKSSON, P.G. 1984. A palaeoenvironmental analysis of the Molteno Formation of the Natal Drakensburg. *Transactions of the Geological Society of South Africa* **87**, 237–244.

GALTON, P.M. & UPCHURCH, P. 2004. Prosauropoda. **In**: Weishampel, D.B., Dodson, P. and Osmólska, H. (eds), *The Dinosauria* (2nd edn), 232–258. Berkeley, University of California Press.

GALTON, P.M. & VAN HEERDEN, J. 1985. Partial hindlimb of *Blikanasaurus cromptoni* n. gen. and n. sp., representing a new family of prosauropod dinosasurs from the Upper Triassic of South Africa. *Geobios* **18**, 509–516.

GALTON, P.M. & VAN HEERDEN, J. 1998. Anatomy of the prosauropod dinosaur *Blikanasaurus cromptoni* (Upper Triassic, South Africa), with notes on the other tetrapods from the lower Elliot Formation. *Paläontologische Zeitschrift* **72**, 163–177.

GOW, C.E. & HANCOX, P.J. 1993. First complete skull of the Late Triassic *Scalenodontoides* (Reptilia Cynodontia) from southern Africa. **In**: Lucas, S.G. and Morales, M. (eds), *The Nonmarine Triassic. New Mexico Museum of Natural History and Science* **3**, 161–168.

KITCHING, J.W. & RAATH, M.A. 1984. Fossils from the Elliot and Clarens Formations (Karoo Sequence) of the northeastern Cape, Orange Free State, and Lesotho, and a suggested biozonation based on tetrapods. *Palaeontologia africana* **25**, 111–125.

LUCAS, S.G. & HANCOX, P.J. 2001. Tetrapod-based correlation of the nonmarine Upper Triassic of southern Africa. *Albertiana* **25**, 5–9.

OLSEN, P.E. & GALTON, P.M. 1984. A review of the reptile and amphibian assemblages from the Stormberg of southern Africa, with special emphasis on the footprints and age of the Stormberg. *Palaeontologia africana* **25**, 87–110.

SEELEY, H.G. 1894. On *Euskelosaurus brownii* (Huxley). *Annals and Magazine of Natural History,* (6) **14**, 317–340.

SMITH, R. & KITCHING, J. 1997. Sedimentology and vertebrate taphonomy of the *Tritylodon* Acme Zone: a reworked palaeosol in the lower Jurassic Elliot Formation, Karoo Supergroup, South Africa. *Palaeogeography, Palaeoclimatology, Palaeoecology* **131**, 29–50

TURNER, B.R. 1972. Revision of the stratigraphic position of cynodonts from the upper part of the Karroo (Gondwana) System in Lesotho. *Geological Magazine* **109**, 349–360.

WELMAN, J. 1999. The basicranium of a basal prosauropod from the *Euskelosaurus* range zone and thoughts on the origin of dinosaurs. *Journal of African Earth Sciences* **29**, 227–232.

WILSON, J.A. & SERENO, P.C. 1998. Early evolution and higher-level phylogeny of sauropod dinosaurs. *Memoir of the Society of Vertebrate Paleontology,* **5**, 1–68.

YATES, A.M. 2003. A definite prosauropod dinosaur from the lower Elliot Formation (Norian: Upper Triassic) of South Africa. *Palaeontologia africana* **39**, 63–68.

YATES, A.M. 2004. *Anchisaurus polyzelus* (Hitchcock): the smallest known sauropod dinosaur and the evolution of gigantism amongst sauropodomorph dinosaurs. *Postilla* **230**, 1–58.

YATES, A.M. 2007*a.* The first complete skull of the Triassic dinosaur *Melanorosaurus* Haughton (Sauropodomorpha, Anchisauria). **In**: Barrett, P.M. & Batten, D.J. (eds), *Evolution and Palaeobiology of Early Sauropodomorph Dinosaurs. Special Papers in Palaeontology* **77**, 9–55.

YATES, A.M. 2007*b.* Solving a dinosaurian puzzle: The identity of *Aliwalia rex* Galton. *Historical Biology* **19**, 93–123.

YATES, A.M., HANCOX, P.J. & RUBIDGE, B.S. 2004. The first record of a sauropod dinosaur from the upper Elliot Formation (Early Jurassic) of South Africa. *South African Journal of Science* **100**, 504–506.

YATES, A.M. & KITCHING, J.W. 2003. The earliest known sauropod dinosaur and the first steps towards sauropod locomotion. *Proceedings of the Royal Society of London, Series B* **270**, 1753–1758.

YOUNG, C.C. 1941. A complete osteology of *Lufengosaurus huenei* Young (gen. et sp. nov.). *Palaeontologica Sinica (series C)* **7**, 1–53.