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Discussion of "Permian—Triassic vertebrate footprints from South Africa: Ichnotaxonomy, producers and biostratigraphy through two major faunal crises" by Marchetti, L., Klein, H., Buchwitz, M., Ronchi, A., Smith, R.M.H., DeKlerk, W.J., Sciscio, L., and Groenewald, G.H. (2019)

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ABSTRACT

A newly devised tripartite subdivision of the Karoo Basin, South Africa, is based on a number of vertebrate-trackways spanning the Middle Permian (Wordian/Capitanian) to Lower Triassic (reportedly Induan) rocks of the Beaufort Formation. The youngest Footprint Assemblage (FA III) is reported to occur in the lowermost Triassic rocks of the Palingkloof Member. One collection site from which seven trackways are reported, Bethel farm, is a classic South African locality where some authors place the end-Permian extinction event and, coincidentally, the vertebrate-based terrestrial Permian—Triassic Boundary. Published GPS coordinates for the Bethel farm site, though, indicate that these trackways originate from exposures of the Burgersdorp Formation near the town of Aliwal North. Outcrops here are assigned to the *Cynognathus* Assemblage Zone, and indicate a Middle Triassic age assignment. In addition, we caution the use of any small temporally or spatially restricted dataset, which is of severely limited utility, in making broad generalizations about paleoenvironmental or paleoecological interpretations.

1. Introduction

The recent publication by Marchetti et al. (2019) on the ichnotaxonomy and morphological details of South African trackways, and their relationship to vertebrate turnover in the Beaufort Formation, advances our understanding of late Paleozoic tetrapods in this part of Pangea. The implementation of photogrammetric methods, in conjunction with the creation of false-color maps to demonstrate manus-and-pes relief, is an advance to help discriminate features of ten ichnotaxa in the region. Based on their revision of this tetrapod ichnological record and its stratigraphic distribution, they delineate three, distinct footprint assemblages, FA I to FA III. The recognition of these assemblages provides additional criteria to help characterize stratigraphic intervals where neither vertebrate skeletal remains nor palynological assemblages may be preserved. Using this complementary data set, Marchetti et al. (2019) propose several hypotheses about the vertebrate response to reported perturbation during the Guadalupian and latest Changhsingian where, in the latter succession, some authors report the presence of the terrestrial expression of the end-Permian extinction event (e.g., Ward et al., 2000, 2005; Smith and Botha-Brink, 2014; Viglietti et al., 2018).

Footprint Assemblage III described by Marchetti et al. (2019) is comprised of trackways reported from sites near Middelburg and Colesberg, where the stratigraphic position of these horizons are presumed but not definitive, and Bethel farm (BE) in the Free State. Specimens are reported to originate from the lowermost exposures of the *Lystrosaurus* Assemblage Zone in the Palingkloof Member, using the Bethel farm as reference, and all are assigned an Induan age. The ichnotaxa from Bethel farm are cf. Dicynodontipus isp. (BE-TR7; tables 2–3, p. 147), *Dolomitipes accordii* (BE-TR1, 3, 4; BE1, 3; tables 1–3, p. 146, 1477) *Dolomitipes* isp. (BE-TR2, 5; tables 1–2, p. 146, 147), and *Rhynchosauroides* isp. (BE-TR6; table 2, p. 147). Marchetti et al. (2019, p. 162) state that their Bethel-farm trackways "*are stratigraphically placed 15 m above [the] top of the main extinction phase the [that] marks the end-Permian in that section, i.e. within the Lystrosaurus AZ (Smith and Botha-Brink, 2014).*"

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While this represents an important contribution we are concerned with the interpretation of "…a *heavily-trampled surface with hundreds of footprints of relatively small size*…" at the Bethel locality as being indicative of the "…*initial phase of a stressed, surviving tetrapod community… that is consistent with the early phases of faunal recovery*…", and especially how this may be misinterpreted by subsequent researchers. While this is certainly a valid hypothesis to consider, it is never tested in this contribution by Marchetti et al. and is therefore inadmissible as evidence supporting any paleoenvironmental models (Marchetti et al. 2019, p. 163-164).

It is importance to recognize that for the above interpretation to be correct the following conditions need to be met:

1. The presence of a reliable, lithological datum that allows the correlation of individual sections both within, and between widely spaced (tens to hundreds of kilometers) fossil localities. The existence of such a datum is an fundamental precondition necessary to accurately determine the stratigraphic position of any fossil (or relevant geological samples) necessary to establish a high resolution model of faunal turnover and environmental change proposed for the End-Permian in the Karoo.
2. The availability of high resolution and stratigraphically accurate, paleontological data, especially as it relates to any local or regional datum.
3. That the trackway dataset can be considered representative of the ancient biotic community.

With regards to the first assumption our views on lateral lithofacies variation in the upper Balfour Formation, as well as the implications of our findings on the veracity of the proposed extinction datum, has been well documented (Gastaldo et al., 2009, 2019, in press; Gastaldo and Neveling, 2016) and will not be repeated here.

Approximately 70% of the vertebrate-fossil record on which the widely accepted end-Permian turnover model is based originates from the Bethel locality, which is situated approximately 30 km east of the town of Bethulie in the southern Free State Province of South Africa. It is centered on the farm Bethel 763, but often also include fossils collected from the exposures on the adjacent farms Heldenmoed 677, Donald 207 (also referred to as Fairydale), as well as the lesser known Stillerust 675. The stratigraphic interval reported to contain the purported end-Permian vertebrate extinction event, figured by Smith and Botha-Brink (2014, their fig. 4), is located at S 30° 25.062′, E 26° 16.006′ (Gastaldo et al., 2009, 2019; Neveling et al., 2016).

Our research team has spent considerable time at this locality and has acquired more than 400 waypoints (WGS84 standard) over this area of ~6 km^2. These waypoints complement the 261 GPS coordinates of vertebrate collection sites documented, here, and provided to us by Dr. Roger Smith (pers. comm. email dated 19 Feb 2014). Exposures at the larger "Bethel" locality are generally limited to shallow gulleys and restricted hillslopes exposures and we therefore appreciate the challenges that researchers have to contend with documenting the stratigraphic position of any paleontological or geological datapoint. As previously demonstrated (Gastaldo et al. 2009, 2018, in press) a robust stratigraphic model requires high-resolution GPS data to be superimposed upon a stratigraphic framework consisting of spatially dispersed sections that have been physically correlated. To maintain high levels of confidence, it is essential that all GPS coordinate data be supported with information on the accuracy, time and date of the actual recording, as well as the coordinate system used. Other strategies to consider include taking multiple readings using multiple devises.

The GPS coordinates for vertebrate trackway reported by Marchetti et al. (2019) from the Bethel farm do not meet the above requirements; they plot neither in close proximity to this site nor within the dense cluster of our waypoint database (Fig. 1). Instead, the collection site of trackways used, in large part, to circumscribe FA III, plots on the farm Rietpoort 67 in the Joe Gqabi district near Aliwal North, ~30 km southeast of the Bethel locality (Fig. 1, yellow pin). The succession at Rietpoort is assigned to the Burgersdorp Formation (Johnson et al., 2006) and preserves vertebrates of the *Cynognathus* Assemblage Zone (Neveling, 2004). To date, no radiometric ages have been reported from the Burgersdorp Formation, but until Ottone et al.'s (2014) date for the *Cynognathus* AZ can be replicated, or not, in South Africa, this biozone could be as young as Middle Triassic in age.

Hence, we only can conclude that specimens used by Marchetti et al. (2019) to define their FA III zone are neither from the *Lystrosaurus* AZ nor Induan in age as reported, or that the coordinates for Bethel locality, as happened before (e.g., Ward et al., 2005) have been reported incorrectly. It is in the interest of the scientific community and future scientific research, to obtain clarity on the accurate location of the Bethel footprint assemblage. If the latter assumption is correct, but security concerns prohibit such detail from being made publically available, we beseech the authors to indicate its general position. More specifically, it is important for the research community to know whether the footprint locality originates from the valley on which the published Bethulie section (Smith, 1995; Smith and Botha-Brink, 2014; Gastaldo et al., 2019) has been based. Should this locality be located on the eastern part of Bethel 763, or the adjacent farms Stillerust 675 or Donald 207, we question the basis on which the highly specific stratigraphic position, 15 m above the faunal turnover, was arrived at.

Fossil track sites represent, by preservational necessity, events of very short duration (hours to weeks) and require unique taphonomic conditions for their formation and preservation. While Marchetti et al. (2019) did not report on the dimensions of the various footprint paleosurfaces, it is unlikely that these paleosurface areas, formed over a very short period, were of sufficient extent to ensure that they captured a sufficiently representative sample of the vertebrate community, to allow extrapolation on the vertebrate community structure representative of a much longer (10^3–10^4 year) period. In contrast, the available dataset is too small to allow any robust conclusions to be made on the health of the tetrapod community, especially if such conclusions are dependent on the absence of data and the two ichnoassemblages are, essentially, identical (e.g., displaying only slight differences in taxonomic and size diversity). As it stands, any correlation of the Bethel footprint locality with postulated environmental models is overly dependent on the existing paradigm for the end-Permian in the Karoo, indicating reasoning analogous to the Confirming Evidence Trap Hammond et al. (1998) or Availability and Anchoring biases described by Krueger and Funder (2004).

2. Conclusions

A new tripartite subdivision of the Beaufort Group, Karoo Basin, is proposed by Marchetti et al. (2019) on vertebrate-footprint assemblages ranging from the Guadalupian (FA I) to the Induan (FA III), the latter defined by several collections reported from the Palingkloof Member. Several of these collection sites near Middelsburg and Colesberg are unconstrained stratigraphically (Marchetti et al., 2019, p. 144), with one locality targeted as providing a definite attribution to the *Lystrosaurus* Assemblage Zone following the end-Permian model of Smith and Botha-Brink (2014).

Plotting the GPS coordinates of Marchetti et al. (2019) shows the reported collection site of specimens BE1, BE 2, and BE-TR 1, BE-TR-3 and BE-TR-4 (*Dolomitipes accordii*), BE-TR 2 and BE-TR 5 (cf. *Dolomitipes* isp.) 7, BE-TR 6 (*Rhynchosauroides* isp.), and BE-TR 7 (cf. *Dicynodontipus* isp.) to originate from exposures of the Burgersdorp Formation near the town of Aliwal North. Outcrops here have been assigned to the *Cynognathus* Assemblage Zone (Neveling, 2004; Van der Walt et al., 2010) rather than those reported to originate from the *Lystrosaurus* Assemblage Zone. Alternatively the reported Bethel footprint site may reside at a different set of coordinates. Irrespective of the outcome, the correlation of this assemblage with the main section at Bethel (Smith,

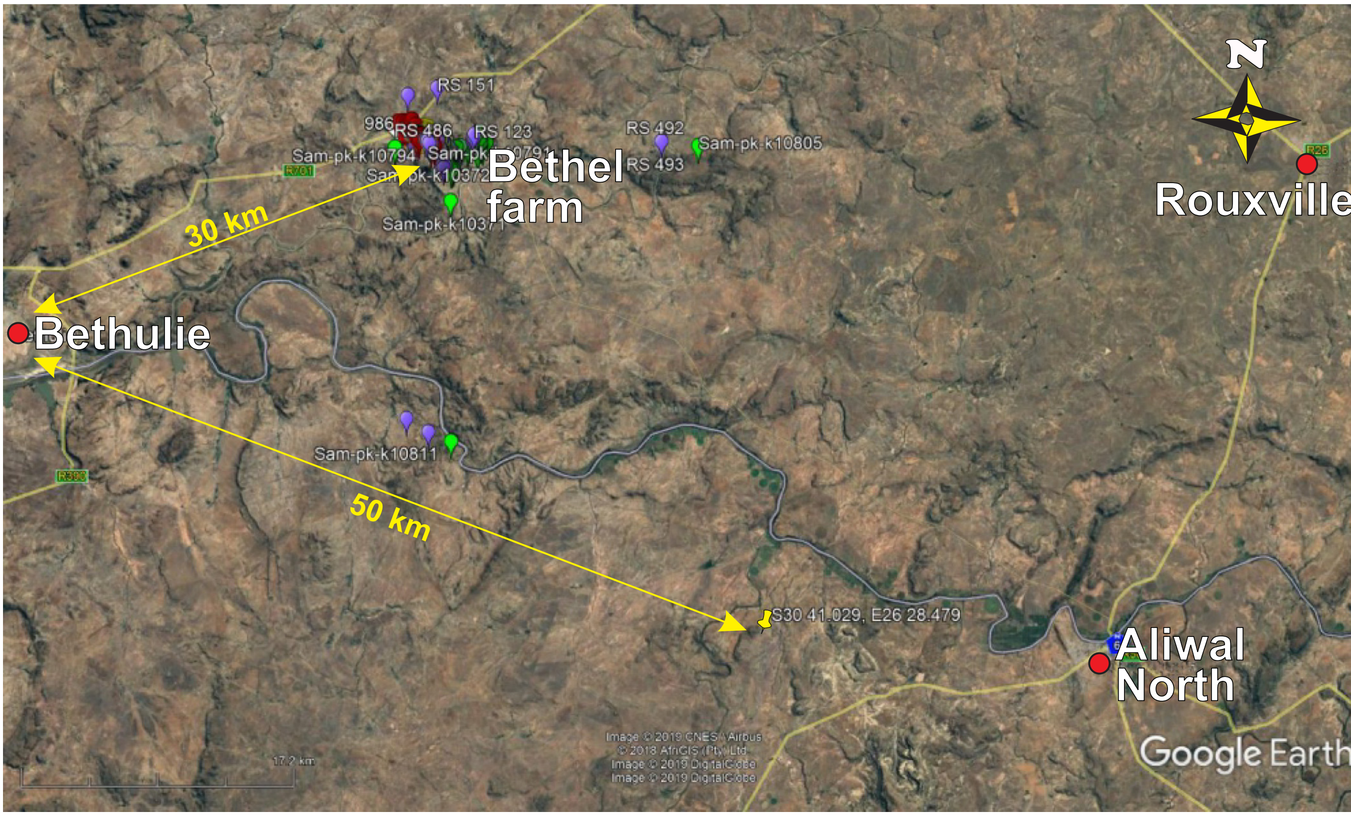

Fig. 1. GoogleEarth plot of GPS coordinates for data sets originating from Bethel Farm (e.g., Gastaldo et al., 2009, 2019) and Marchetti et al. (2019) demonstrating their incongruence. Bethel farm coordinates plot ~30 km east of Bethulie, whereas the coordinates provided by Marchetti et al. (2019) for their collections purportedly recovered from the Palingkloof Member at that site plot 50 km to the southeast near the town of Aliwal North. The rocks in-and-around Aliwal North are assigned to the Burgersdorp Formation, and are Middle Triassic or younger in age. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

1995) remains unclear and we look forward to receive clarification from the authors.

Marchetti and co-workers should be commended for their contribution to document and analyze the ichnological record of the Adelaide Subgroup (Beaufort Group). Yet, there dataset is still very small and is, therefore, of severely limited paleoenvironmental or paleoecological utility. Hence, Marchetti et al.'s (2019) interpretation that the ichnological assemblage of vertebrate trackways defining their FA III may represent evidence for a stressed environmental setting, without taking the limitations of their database into account amounts to irresponsible speculation. We are unable to comment on the relationship of other trackway-collection sites to any other well constrained stratigraphy, and must rely on other South African workers to test the remaining data set.

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