

The terrestrial Permian–Triassic boundary event bed is a nonevent

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We welcome the fact that Gastaldo et al. (2009) have been continuing research in the Karoo of South Africa; those of us who have worked there know how important new research in this area is if we are to ever understand the causes of the Permian–Triassic mass extinction on land. However, here we would like to correct several matters arising from their paper.

Their paper focuses on laminated beds that we first described near the paleontologically defined Permian–Triassic (P/T) boundary in South Africa (Smith and Ward, 2001; Retallack et al., 2003; Ward et al., 2005). This unit is, in their own words, “critical to models of end-Permian mass extinction” (Gastaldo et al., 2009, p. 199). But their discussion of this unit concerns time, rather than environmental change occurring in this basin over the Late Permian through Early Triassic interval—a time interval that we recognized by bio-, magneto-, and chemostratigraphy—not solely, or even importantly by lithostratigraphy, as inferred by Gastaldo et al. Our identification of this unit was meant to point out environmental conditions, not to identify a chronological time marker, yet the Gastaldo et al. paper makes the point that this was our sole basis for recognizing the P/T boundary in this region. In fact, we used standard methods of vertebrate biostratigraphy integrated with magnetostratigraphy and chemostratigraphy.

We have noted that the laminite facies characterizing the unit in question is more widespread at the boundary than elsewhere, but our own paleosol data (Zam and Pawa paleosols of Retallack et al., 2003, their figure 4) indicate “laminites” at, above, and below the boundary. In fact, no single lithostratigraphic feature can be used to mark the P/T boundary, unlike the Cretaceous–Tertiary (KT) boundary, for instance, which is both isochronous and usually lithologically unmistakable. Claystone breccias near the P/T boundary (Retallack, 2005), the last coal before the boundary (Retallack et al., 1996), and the incoming of braided streams above the boundary (Ward et al., 2000) are general guides as well, but do not pinpoint the life crisis either. As in any biostratigraphic boundary, it is the fauna that defines boundaries. Continued biostratigraphic collecting at the Bethulie localities resulted in a refinement of the sequence of Permian taxa that disappeared in the strata leading up to the red laminate mudrock facies at the Bethulie site (Smith and Botha, 2005; Botha and Smith, 2006). The P/T boundary coincides with a nodular horizon at the top of the laminite event bed, with Permian fossils *Lystrosaurus mccaigi* and *Moschorhinus* sp. found in the laminites. The presence of these laminated beds near the paleontologically defined and major mass extinction is but one clue useful in testing hypotheses relating to the larger and more interesting questions dealing with the causes of the extinction itself.

The reality is that, even in spite of our long efforts in this region, more fossil datums are needed. Unfortunately, Gastaldo et al. report no new fossils and are mistaken about the stratigraphic levels of our fossils. Our Late Permian *Moschorhinus* from the western side of the valley is not from laminites or from the top of the section (as marked in the Bethel west section of Gastaldo et al. (2009, their figure 2A and figure 3 left-hand

side), but from its base, 10 m lower. They may have been misled by a separate specimen of *Moschorhinus* found in laminites on the eastern side of the valley (noted in the measured section of Retallack et al., 2003, their figure 4C). Other Permian fossils from comparable levels on the western side of the valley are *Dicynodon lacerticeps*, *Lystrosaurus mccaigi*, and *Ictidosuchoides*, all of Permian age. Our detailed maps of fossil occurrences in this small area show no Permian fossils above the *Moschorhinus* level on either side of the valley, but mainly Triassic *Lystrosaurus*. Other evidence for a Triassic age of most of the two sections measured on the western side of the valley by Gastaldo et al. are the red (5YR) rather than purple (10R) color of the paleosols, their deep (>30 cm) calcic horizons, and common vertebrate burrows (clearly shown on the figure in GSA Data Repository item 2009056 of Gastaldo et al.). These are Triassic (Karie) not Permian (Num) red paleosols in the scheme of Retallack et al. (2003). In summary, we did not find our Permian vertebrates in the fine-sand “laminites” high on the west side of the valley. The western sections measured by Gastaldo et al. are mostly Triassic, unlike the clayey and silty “laminites” with Permian fossils on the eastern side of the valley.

In summary, if the P/T boundary event was caused by a large body impact, a single sedimentary “disaster” bed could be expected. But our biostratigraphic data accumulated over decades, coupled with our discovery of multiple carbon isotope swings that extend from before the boundary to levels well into the Lower Triassic (Ward et al., 2005), tell a very different tale. The record for the non-marine world at the end of the Permian is consistent with a series of carbon cycle crises and mass extinctions. The laminated beds played a witness part in this: they were deposited during a probable succession of apparent “dead zones,” when extinction pulses led to reduced bioturbation in pond facies. This is the interesting aspect of this facies—not as a time marker as confused by the Gastaldo group in apparently misunderstanding our papers, but as a clue to the cause of the extinction(s).

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