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Anatomy of a mass extinction: new data on the timing of rapid environmental change and extinction phases at the Permo-Triassic boundary in the main Karoo Basin, South Africa

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The southern part of the Karoo Basin of South Africa contains a near complete stratigraphic record of the Permo-Triassic boundary (PTB). We have found 692 in-situ vertebrate fossils within 200 metres of the PTB at four widely-separated locations in the southern Karoo Basin. Biostratigraphic ranges of the various taxa found in each of the sections reveal three separate phases of die-off within the same roughly 75 metre-thick stratigraphic interval displaying the same sequence of sedimentary facies interpreted as indicative of climatic drying, increased seasonality and the onset of an unpredictable monsoon-type rainfall regime.

With no indication of major hiatus surfaces within the 75 m thick PTB intervals we used the sedimentological record to estimate the time involved. Our temporal resolution is based on estimated floodplain accretion rates of 4.5mm/year with periods of non-deposition quantified by pedogenic maturity of 10 000 years for Stage I and 15 000 years for Stage II carbonate horizons. These were calculated for each stratigraphic section using a de-compaction correction of 5 for overbank mudrocks and 3 for channel sandstones. Using this methodology, and averaging over the 4 study sections the three phases of an inferred ecologically-stepped extinction are estimated to have occurred over a period of ~120 000 years.

Phase 1 lasting an estimated 35 000 years was brought on by lowered water tables, which led to the loss of shallow rooting groundcover in the more elevated proximal floodplain areas and the disappearance of the smaller groundcover-grazing herbivorous dicynodonts and their attendant small carnivores. After a period of stasis lasting some 50 000 years, Phase 2 die-off began. This is considered the main extinction event that occurs in massive maroon/grey mudrock culminating in an event bed of laminated reddish-brown siltstone/mudstone couplets. This facies reflects progressively unreliable rainfall leading to vegetation loss in proximal and distal floodplain areas. The larger tree-browsing herbivores and their attendant carnivores were confined to watercourses before finally disappearing. A longer period of relative stasis followed when no disappearances are recorded, however, some new immigrant taxa, notably proterosuchian archosauromorphs, appeared as part of this earliest Triassic fauna before the Phase 3 die-off, that lasted approximately 10 000 years. This last phase of the mass extinction is preserved as massive maroon siltstone facies with evidence of climatic aridity including the accumulation of mummified carcasses buried by windblown dust. All of the surviving Permian taxa disappeared within 30 m of the PTB. We propose that the recorded disappearances are real (rather than preferential preservation failure) and that they represent drought-induced die-offs moving progressively up the food chain as the terrestrial ecosystem collapsed.

New data from the most recent PTB investigations supports earlier studies indicating that the terrestrial vertebrate-defined PTB in the Karoo Basin is an expression of the main end-Permian mass extinction event. Isotopes and a preliminary zircon date from a recently discovered tuff bed at 9 meters below the PTB supports the assertion that the terrestrial and marine extinctions were in fact synchronous and linked.