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Cycle-calibrated magnetostratigraphy and time scales for the Early and early-Late Triassic

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The Triassic marks an unusual period in Earth history with a unique paleogeography, mass extinctions, huge volcanic eruptions, etc. After the end-Permian mass extinction, a prolonged and unstable biotic recovery continued through the Early Triassic with punctuations by recurrent anomalously hot climate episodes, carbon-cycle perturbations and global ocean anoxia. During middle Carnian (Late Triassic), the former long-lived Yangtze Platform of the South China Block was terminated by an influx of clastic-rich sediments, which potentially correspond to the Schilfsandstein that defines the Carnian Humid Episode (CHE) in Europe, a significant global disruption of Earth's climate-ocean-biological system. Nevertheless, understanding the temporal relations of these dramatic events is hindered mainly by lack of an accurate time frame. For example, the span of the Carnian stage has been estimated to range from ca. 16 myr to 8.5 myr, depending upon the choice between “long-Tuvalian/short Norian” or “short-Tuvalian/long Norian”. Here we propose a high-resolution time scale for the Early Triassic (Induan-Olenekian) and Late Triassic (Carnian), respectively, by applying integrated stratigraphic tools such as cyclostratigraphy, magnetostratigraphy, biostratigraphy to Triassic sediments from South China and the Germanic Basin.

Early Triassic (Induan-Olenekian). Astronomical-cycle tuning of spectral gamma-ray logs from biostratigraphically-constrained cyclic stratigraphy through marine sections at Meishan, Chaohu, Daxiakou and Guandao in South China yields an integrated time scale for the Early Triassic, which is consistent with scaling of magnetostratigraphy from climatic cycles in continental deposits of the Germanic Basin. The main marine mass extinction interval at Meishan is constrained to less than 40% of a 100-kyr cycle (i.e., < 40 kyr). The sharp positive shift in $\delta^{13}C$ from –2‰ to 4‰ across the Smithian-Spathian boundary at Chaohu took place within 50 kyr. The durations of the Griesbachian, Dienerian, Smithian and Spathian substages are 1.4 ±0.1, 0.6 ±0.1, 1.7 ±0.1 and 1.4 ±0.1 myr, respectively, with uncertainty based on the placement of conodont zones, implying a span of 5.1 ±0.1 myr for the Early Triassic. Thus, using 251.902 ±0.024 Ma for the Permian-Triassic boundary from Meishan GSSP, the ages of substage boundaries are 250.5 ±0.1 Ma (base Dienerian), 249.9 ±0.1 Ma (base Smithian or base Olenekian), 248.2 ±0.1 Ma (base Spathian), and 246.8 ±0.1 Ma (base Anisian). This astronomically-calibrated reference time scale enables us to constrain the timing and rates of recurrent carbon isotope excursions and rates of sedimentation documented in the Early Triassic of South China and elsewhere.

Late Triassic (Carnian). Detailed cyclo-and-magnetostratigraphic analysis was conducted on three lower Carnian sections in South China. A cycle-tuned magnetic polarity scale spanning ~2.4 myr was established, which is featured by a relatively long (1.3 myr) reversed-polarity zone with brief normal-polarity intervals that is consistent with the significant reversed-dominated interval striding the boundary of *T. aonoides* and *A. austriacum* ammonoid zones (late Early Carnian). The distinctive upward

change from a dominance by reversed polarity to normal polarity just after the onset of clastic-rich sedimentation over the Yangtze Platform is also recorded in magnetostratigraphy of the lower Schilfsandstein in the Germanic Basin. Therefore, we conclude that the termination of the Yangtze Platform is coeval with the CHE. The Carnian time scale from South China supports the “Short-Tuvalian/Long-Norian” age model of the Late Triassic, implying that the base of the cycle-tuned polarity pattern from the Newark Supergroup of eastern North America lies in Tuvalian.