Response to Comment on “Lethally Hot Temperatures During the Early Triassic Greenhouse”

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Goudemand et al. replotted a subset of our well-constrained data using a new Early Triassic biostratigraphic scheme based on a lower-resolution ammonoid zonation scheme and hypothetical ammonoid-conodont correlation to produce a less distinct seawater temperature history. We dispute their unsubstantiated correlation and, consequently, their allegations.

Goudemand et al.’s (1) Comment is primarily concerned with the age model that we use to plot our isotopic measurements. This is based on high-resolution sampling and identification of well-established ammonoid zones involving many age-constrained points (2). Our age assignments are also independently supported by a detailed carbon isotope curve that replicates the well-known oscillations of this interval, first identified in detail by Payne and colleagues in South China (3) and subsequently found at numerous locations across the world. Goudemand et al. (1) eschew both the conodont biostratigraphic and C isotope chemostратigraphic correlation and replot a subset of our data on an unpublished, lower-resolution, ammonoid-based biostratigraphic scheme. The result is a much more ‘blurred’ oxygen and carbon isotope record that shows the same overall trends (e.g., peak Smithian warmth) but with none of the finely focused details remaining.

This reevaluation is highly flawed. Goudemand et al. (1) plot the lowest and highest data points within a biozone at the base and top of the respective zone and thus create a purely artificial clustering of data. In fact, our data were located precisely within sections and zones, a precision lost by Goudemand et al. (1). It should be noted that our biostratigraphic dating is based on many more sample points than the isotope data points because not all samples yielded enough conodont material for oxygen isotope analysis. It is also odd that Goudemand et al. choose to replot data onto an ammonoid zonation scheme that is unpublished and shows large discrepancies with the generally accepted Early Triassic biostratigraphy (4, 5). The use of this alternative time scale is especially strange when the time resolution below the mid-Smithian level is much worse than that provided by conodonts (nine conodont zones versus two ammonoid zones). It is therefore ironic that they criticize us for using a biozonation that “is not resolved enough to capture such dynamics.” Furthermore, the ammonoid zonation of Goudemand et al. (1) is based on a mixture of Tethyan and Boreal fossils and is not easily applicable to Tethyan strata of South China. Problems with their scheme are shown by inconsistencies with radiometric ages. Thus, Goudemand et al. (1) assign an age of 247.9 million years for the Early-Middle Triassic boundary, whereas in Sun et al. (2) an age of 247.2 million years is given, which is in agreement with (6) and very close to the 247.1 million years given by Geological Time Scale 2012 (4). For unknown reasons, Goudemand et al. (1) choose not to replot all of our data, and other data points have had their age assignment inexplicably changed. For example, having revised the Chungsingian conodont zonations and assumed equal durations, for no specified reason, they replotted only 19 of our 47 data points in this interval. Also unexplained are many age reassignments that include squeezing upper-middle Spathian data points into the lower-middle Spathian. Goudemand et al. (1) also spuriousely exclude data points measured on Platylvillicosus because this taxon is “presumably a shallower water genus”—we fail to see why this invalidates these data—while low δ18O values of Smithian samples from the Laren and Jiangong sections are invalidated from interpreting high temperatures, again for no reason. They also argue that the offset in the oxygen isotope ratios of conodonts from the Zuodeng sections and the Bianyang quarry, Jiangong, and Laren sections cannot be explained by a difference in water depth because the analyzed taxa belong to the same genus. However, representatives of the same genus can have different water-depth preferences (7). The alternative, that the offset is better explained by thermal alteration (1), is devoid of any evidence because thermal overprint does not necessarily imply a change in the oxygen isotope composition of phosphate-bound oxygen (8). The peak of late Griesbachian warmth is defined by three data points from two sections and would obviously be better constrained with more data, but Goudemand et al. choose to plot only two points and incorrectly move the other point into the lower Dienerian and erroneously conclude that this younger stage was warmer than the Griesbachian. Our carbon isotope data are also subject to unexplained replotting even though the trends we showed are nearly identical to those of previous studies (3, 9). For example, the δ13C maximum at the Dienerian/Smithian is seen in other studies (3, 9), but this becomes an intra-Smithian maximum in their replot.

In response to the specific points of Goudemand et al., we reappraised table S4 of the supplementary materials for (2) and acknowledge that 5 of the 112 samples listed have incorrect age assignments. Thus, samples ZDC50 and ZDC51 (instead of ZDC52 and ZDC 53) were erroneously listed in the Icriopsathodus collinsoni zone but are from the Neospathodus pingdingshanensis zone. In addition, a middle Ic. collinsoni rather than a middle Ns. homeri zone has to be assigned to sample ZDC32. However, importantly, all samples are correctly plotted in figure 2 of the main text (2). Their claim that Parachirognathus is not known from the Spathian of South China is wrong [see (10, 11)], so they should not redate our sample BYC19-1. The fish fauna of Jurong has long been recognized to be of Dienerian age (12), not the Smithian as they claim. The material of Tong et al. (13) is the only confirmed fish fauna of possible Smithian age in South China, as listed in our supplementary materials. These low-latitude Smithian fishes were neither di verse nor abundant and contrast markedly with the fossil fish record from higher paleolatitudes. Goudemand et al.’s (1) final observation, that the potentially warm world of the Middle Ordovician was associated with rapid radiation and that radiation should be therefore seen in the Early Triassic, also shows a superficial understanding of our claims. We show that the “ lethally hot temperatures” were a facet of equatorial latitudes while conditions at higher latitudes were cooler and that these latitudes do indeed show much earlier ecosystem recovery (14). For example, the Early Triassic saw the appearance and radiation of ichthyosaurs at this time in higher latitudes. A very sluggish benthic recovery in the Early Triassic may reflect the widespread prevalence of marine anoxia (15), a factor that may not have been involved during Ordovician radiation.

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In summary, Goudemand et al.’s (1) replotting of our data set is a fine example of scientific legerdemain: selective replotting of a subset of our data at a lower resolution using an ammonoid zonation scheme that is poorly cross-correlated with a well-established conodont biostratigraphic scheme.

References
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