Comment and Reply
CO_2 as a primary driver of Phanerozoic climate
Dana L. Royer, Robert A. Berner, Isabel P. Montañez, Neil J. Tabor, and David J. Beerling, GSA Today, v. 14, no. 3, p. 4–10.

Comment

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Royer et al. (2004), in their recent article in *GSA Today*, dispute the conclusion of Shaviv and Veizer (2003) that celestial forcing may have been the major driver of Phanerozoic climate, arguing instead for CO_2 as the dominant force. The $\delta^{18}O$ of calcareous shells reflects the ambient temperature of seawater and the quantity of water locked in the polar ice caps, each contributing about one half to this signal, but lately it has been realized that seawater pH drives the $\delta^{18}O$ in the opposite direction. Royer et al. utilized this for reconciling the GEOCARB III and the $\delta^{18}O$ trend of Veizer et al. (2000) by assuming that any discrepancy of the two variables is due to pH. This is an interesting proposition that has some merit, but note that such a correction is entirely arbitrary, because we do not have any constraints for the pH of Phanerozoic seawater, except possibly some boron isotopes for the youngest portion of this record. Moreover, the pH correction itself basically reflects the GEOCARB III CO_2 model, such that the correlation obtained between the corrected $\delta^{18}O$ and CO_2 cannot be claimed to be a CO_2 fingerprint. Furthermore, the model of Royer et al. does not consider the mitigating "ice volume" effect. Once included, the required pH correction (and GEOCARB III CO_2 levels) would have to be about doubled for CO_2 climate "driving" to be on par with the CRF. For all these, and the reasons listed in our detailed response (see www.gsajournals.org; go to "Online Journals," then "Online Forum"), we argue that the $\delta^{18}O$ trend is still chiefly a reflection of the temperature history of the past oceans, controlled principally by the celestial driver.

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Reply

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A major purpose of our paper was to show that paleotemperature records do not support the presence of prolonged cold intervals (similar in magnitude and duration to the Permo-Carboniferous glaciation) during the Ordovician/Silurian (460–400 Ma) and mid-Mesozoic (220–120 Ma), as required by the $\delta^{18}O$ record of Veizer et al. (1999). The fact that our pH-corrected curve better matches the more robust record of glacial sediments should be taken as a positive result, considering an alternative explanation of diagenesis. Crucially, diagenetic overprinting can be present even when screening samples using the petrographic and trace element criteria adopted by Veizer et al. (1999) (cf. Montañez et al., 2000; Wenzel, 2000; Mii et al., 2001; Pearson et al., 2001).

Shaviv and Veizer claim that we correlate the CO_2 and pH-corrected temperature records. This is simply untrue. Also, their "ice volume" effect, to be applied to our pH correction, is based on an average slope for the change in temperature with $\delta^{18}O$, for the entire Phanerozoic. This approach is incorrect. The ice volume correction is applicable only to periods of major glaciation, but at these times our pH correction was minor.

The correspondence between the Phanerozoic records of atmospheric CO_2 and glacial sediments, and the revision of the $\delta^{18}O$ paleotemperature record toward values better matching the glacial sediment record, strongly implicate CO_2 as a primary driver of climate over these timescales. Cosmic ray flux is likely only of second-order significance (see also Rahmstorf et al., 2004).

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