Science AAAS

Response to Comment on "Atmospheric P_{CO_2} Perturbations Associated with the Central Atlantic Magmatic Province"

Morgan F. Schaller, *et al.*

Science **334**, 594 (2011);
DOI: 10.1126/science.1209422

This copy is for your personal, non-commercial use only.

If you wish to distribute this article to others, you can order high-quality copies for your colleagues, clients, or customers by clicking here.

Permission to republish or repurpose articles or portions of articles can be obtained by following the guidelines here.

The following resources related to this article are available online at www.sciencemag.org (this infomation is current as of November 3, 2011):

Updated information and services, including high-resolution figures, can be found in the online version of this article at:
http://www.sciencemag.org/content/334/6056/594.3.full.html

This article **cites 13 articles**, 5 of which can be accessed free:
http://www.sciencemag.org/content/334/6056/594.3.full.html#ref-list-1

This article appears in the following **subject collections:**
Atmospheric Science
http://www.sciencemag.org/cgi/collection/atmos
Technical Comments
http://www.sciencemag.org/cgi/collection/tech_comment

Downloaded from www.sciencemag.org on November 3, 2011

Science (print ISSN 0036-8075; online ISSN 1095-9203) is published weekly, except the last week in December, by the American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005. Copyright 2011 by the American Association for the Advancement of Science; all rights reserved. The title *Science* is a registered trademark of AAAS.

Response to Comment on "Atmospheric P_{CO_2} Perturbations Associated with the Central Atlantic Magmatic Province"

Morgan F. Schaller,[1]* James D. Wright,[1] Dennis V. Kent[1,2]

Rampino and Caldeira argue that the first pulse of the Central Atlantic Magmatic Province would increase the concentration of atmospheric carbon dioxide (P_{CO_2}) by only 400 parts per million if erupted over 20,000 years, whereas we observed a doubling within this interval. In the absence of any data to the contrary, we suggest that a more rapid (≤1000-year) eruption is sufficient to explain this observation without relying on thermogenic degassing.

Our observations from the Newark Basin indicate that the first pulse of the Triassic-Jurassic Central Atlantic Magmatic Province (CAMP), represented by the Orange Mountain Basalt, was emplaced within a precession cycle and resulted in a doubling of the atmospheric partial pressure of CO_2 (P_{CO_2}) above pre-eruptive background levels. A simple model with instantaneous degassing [<1 thousand years (ky), within the time scale of ocean overturning] of 2.5×10^{17} moles of CO_2 ($\sim 1.2 \times 10^{16}$ kg), roughly the efflux potential of the first volcanic pulse, gives a ~1400 parts per million (ppm) increase in P_{CO_2} above the ~2000-ppm background level (*1*). This estimate is compatible with and (admittedly, barely) within the error of the doubling from ~2000 to 4400 ± 1200 ppm observed in the Newark Basin. Rampino and Caldeira (*2*) present a model whereby a 20-ky release of the same magnitude produces only a ~400-ppm atmospheric P_{CO_2} increase, which they take as an indication that an additional source of CO_2 is necessary to explain the observed P_{CO_2} increase. We do not dispute this point, but it begs qualification.

The cycle stratigraphic record from the Newark Basin provides a constraint on the maximum duration (<20 ky) of the first pulse of magmatism, but we are not aware of any data (e.g., weathering at the tops of individual lava flows or accumulation of sediments between flows) that preclude a much more rapid release. Therefore, these release-time constraints provide two useful end-member scenarios to explain the observed changes in P_{CO_2}: Either the CO_2 release was rapid and could be almost exclusively volcanogenic, or it was more protracted, which would require nearly 10 times as much CO_2 [e.g., see (*3*, *4*)] [10^{17} moles atmospheric reservoir versus 10^{18} moles atmosphere-ocean reservoir (*5*–*8*)], opening the possibility that it may be thermogenic in origin.

Because thermogenic evolution of CO_2 from $CaCO_3$ sediments is an unlikely source [e.g., see (*9*)], the next largest reactive carbon pool in Earth's crust is organic, which implies that the extra CO_2 needed for a protracted release would be relatively depleted in ^{13}C. However, the organic carbon $\delta^{13}C$ measurements from the Newark Basin (*1*) do not indicate a substantially larger ^{13}C-depleted component in the overall atmospheric P_{CO_2} increase, although there is a slight $\delta^{13}C$ decrease (~0.5 per mil) above each volcanic unit. We note that some marine sections record a potential light carbon-isotope excursion at about this time (*10*); however, the exact relationship of the marine $\delta^{13}C$ decrease to the CAMP eruptions remains unclear (e.g., see *11*). Moreover, our observation of comparable P_{CO_2} and $\delta^{13}C$ changes after the second and third volcanic events would require a similar thermogenic input if the duration of each pulse was ~20 ky, which would represent a substantial repeated flux of thermogenic CO_2 to the atmosphere at discrete intervals.

Therefore, we are left to speculate on the precise source of the CO_2 pulse recorded in the Newark Basin, which is essentially an argument of release duration versus size. In the absence of any data to the contrary, we favor a rapid release that allows the majority of each perturbation to be volcanogenic but that does not preclude a metamorphic carbon source. The doubling of P_{CO_2} observed after each volcanic unit in the Newark Basin is broadly consistent with other lower-resolution studies that indicate a tripling to quadrupling through the interval (*12*–*14*). The continued challenge to the modeling community is to devise a scenario that conforms to these observations.

[1]Earth and Planetary Sciences, Rutgers University, 610 Taylor Road Piscataway, NJ 08854, USA. [2]Lamont-Doherty Earth Observatory of Columbia University, 61 Route 9W, Palisades, NY 10964, USA.

*To whom correspondence should be addressed. E-mail: schaller@rci.rutgers.edu

References and Notes

1. M. F. Schaller, J. D. Wright, D. V. Kent, *Science* **331**, 1404 (2011).
2. M. R. Rampino, K. Caldeira, *Science* **334**, 594 (2011); www.sciencemag.org/cgi/content/full/334/6056/594-b.
3. D. J. Beerling, R. A. Berner, *Global Biogeochem. Cycles* **16**, 1036 (2002).
4. R. A. Berner, D. J. Beerling, *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **244**, 368 (2007).
5. R. A. Berner, K. Caldeira, *Geology* **25**, 955 (1997).
6. K. Caldeira, G. H. Rau, *Geophys. Res. Lett.* **27**, 225 (2000).
7. R. A. Berner, A. C. Lasaga, R. M. Garrels, *Am. J. Sci.* **283**, 641 (1983).
8. K. E. Trenberth, *J. Geophys. Res.* **86**, (C6), 5238 (1981).
9. D. M. Kerrick, J. A. D. Connolly, *Nature* **411**, 293 (2001).
10. S. P. Hesselbo, S. A. Robinson, F. Surlyk, S. Piasecki, *Geology* **30**, 251 (2002).
11. J. H. Whiteside, P. E. Olsen, T. Eglinton, M. E. Brookfield, R. N. Sambrotto, *Proc. Natl. Acad. Sci. U.S.A.* **107**, 6721 (2010).
12. J. C. McElwain, D. J. Beerling, F. I. Woodward, *Science* **285**, 1386 (1999).
13. D. Beerling, *Nature* **415**, 386, author reply 388 (2002).
14. M. Steinthorsdottir, A. J. Jeram, J. C. McElwain, *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **308**, 418 (2011).

Acknowledgments: This work was supported by National Science Foundation grant 0958867. This is Lamont-Doherty Earth Observatory Contribution 7497.

24 June 2011; accepted 6 October 2011
10.1126/science.1209422

Downloaded from www.sciencemag.org on November 3, 2011