

Interactive comment on “Mass extinctions past and present: a unifying hypothesis” by S. A. Wooldridge

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The paper presents a scenario for a single kill mechanism being responsible for at least four of the big five Phanerozoic mass extinctions. The pH-triggered inactivation of enzyme urease is suggested as the proximate kill mechanism for the Late Devonian, end-Permian, end-Triassic and end-Cretaceous mass extinctions.

The paper is well written; the reasoning is stringent and focused. My major criticism concerns the coverage and discussion of the published literature with respect the timing and causes of extinctions, and the uncritical use of a non-reviewed abstract for the history of oceanic pH. As my expertise is on deep time patterns, I emphasize those in this review.

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Apart from the still unknown role of urease in invertebrates (see reviewer #3), the major problem in this paper is the unknown pattern of pH variations over the Phanerozoic eon. Wooldridge relies strongly on the tentative pH curve figured in an abstract (Caldeira 2007), which is only valid under the assumption of constant surface-ocean carbonate mineral saturation. Because carbonate saturation state is likely to parallel CO₂ concentrations on geological time scales (Caldeira 2007), this is a very unlikely scenario.

Only short term changes in pCO₂ are likely to substantially affect oceanic pH. While these short term changes are feasible under volcanic degassing scenarios, they would require a geologically rapid extinction. A gradual or stepwise extinction pattern, often cited by the author as supporting evidence for his hypothesis, would not agree with these boundary conditions.

The evidence of gradual and stepwise extinction patterns is equivocal. Several of the mass-extinction aspects need to be updated with modern literature. Importantly, the gradual versus abrupt demise of species across mass extinction episodes is not correctly referred to. For example Keller (2001) is cited as showing a gradual demise, but this is wishful thinking. Quantitative evidence either suggests an abrupt extinction (Huber et al. 2002, Paul 2005) or at least confirms that gradual versus abrupt patterns cannot be distinguished based on the available data (Marshall and Ward 1996). In general, geologically sudden environmental changes are evident at almost all mass extinction episodes (Alvarez et al. 1980, Sheehan 2001, Ward et al. 2001) and equally sudden biotic responses are evident at the end-Permian (Jin et al. 2000) and end-Cretaceous mass extinctions. There is no evidence for Norian/Rhaetian extinctions being similar to Rhaetian-Hettangian extinctions (p. 2406). Background extinctions appear to have been high throughout the Late Triassic, but the Rhaetian spike stands out significantly (Kiessling et al., 2007).

The end-Cretaceous extinction is an especially poor candidate for a pH-triggered urease inhibition as a major kill mechanism, because terrestrial and marine faunas

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were similarly affected and because heavily calcifying taxa (e.g., scleractinian corals; Kiessling and Baron-Szabo 2004) showed lesser extinction than some weakly calcifying taxa (e.g., bivalves; Raup and Jablonski 1993). The hypothesis of pathological dinosaur egg shells forwarded by Wooldridge does not agree with stable dinosaur diversity throughout the latest Cretaceous (Fastovsky and Sheehan 2005), neither does it agree with the profound extinction of mammals at the KT (Alroy 2003).

In summary the two cornerstones of Wooldridge's hypothesis (pH variation over the Phanerozoic and enzymatic response to those) are fairly weak. The paper can be saved by (1) acknowledging these uncertainties, (2) accepting the prevalence of sudden extinctions in the fossil record, and (3) and discussing other alternatives be them enzymatic or otherwise.

An enzymatic effect of seawater acidification has also been proposed by Marubini et al. (2008). However, emphasized in this paper is also that the pH within the calcioblastic cells on marine invertebrates is about 7.4 (see also Payan et al., 1983), that is, much lower than the 7.9 value indicated for the "dead zone". I suggest discussing this paper shortly and also the general notion that cytoplasmic pH rarely matches environmental pH.

Minor comments

I would like to see a table in the paper which lists higher groups of taxa which depend on urease activity (with references).

Reference to Culver (2003) is misleading. Culver argues that there is no depth gradient in the extinction of benthic foraminifers and the major difference is between a planktonic and benthic lifestyle irrespective of depth. Please revise! Reference to Jeffery (2001) is incorrect. Jeffery clearly states (p. 148) that there is NO relationship between water depth and extinction risk in heart urchins, which confirms an earlier analysis based on all sea urchins (Smith and Jeffery, 1998). One could also add that azooxanthellate corals were significantly less affected than zooxanthellate taxa at the KT (Kiessling and

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Baron-Szabo 2004). This could be related to a depth gradient.

p. 2402: Definition of mass extinctions. The most important criterion for a mass extinction is that extinction rates are significantly above background. Avoid the term "insignificant" with respect to time. "Brief" or "short" would be better.

p. 2402, l. 26: The Phanerozoic started at 542 Ma.

p. 2403: Rhode and Muller (2005) discuss diversity rather than extinctions. It would be fair to cite Sepkoski here, because his data are behind most later analyses (e.g. Sepkoski 1996).

p. 2405, l. 10: snails are gastropods! Please rephrase!

p. 2406, l. 4: "two pH optima"

p. 2413, l. 4: "most certainly" is perhaps too strong in this context.

References

Alroy, J.: Cenozoic bolide impacts and biotic change in North American mammals, *Astrobiology*, 3, 119-132, 2003.

Alvarez, L. W., W. Alvarez, F. Asaro, and H. V. Michel: Extraterrestrial cause for the Cretaceous-Tertiary extinction, *Science*, 208, 1095-1108, 1980.

Caldeira, K.: Phanerozoic ocean chemistry and anthropogenic ocean acidification, *Geochimica Et Cosmochimica Acta*, 71, A140-A140, 2007.

Fastovsky, D. E., and P. M. Sheehan: The extinction of the dinosaurs in North America, *GSA Today*, 15, 4-8, 2005.

Huber, B. T., K. G. MacLeod, and R. D. Norris. 2002. Abrupt extinction and subsequent reworking of Cretaceous planktonic foraminifera across the Cretaceous-Tertiary boundary: evidence from the subtropical North Atlantic. Pp. 277-289. In C. Koeberl, and K. G. MacLeod, eds. *Catastrophic Events and Mass Extinctions: Impacts and*

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beyond. GSA Special Paper, Boulder.

Jin, Y., Y. Wang, W. Wang, Q. H. Shang, C. Q. Cao, and D. H. Erwin: Pattern of marine mass extinction near the Permian-Triassic boundary in South China, *Science*, 289, 432-436, 2000.

Kiessling, W., M. Aberhan, B. Brenneis, and P. J. Wagner: Extinction trajectories of benthic organisms across the Triassic-Jurassic boundary, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 244, 201-222, 2007.

Kiessling, W., and R. Baron-Szabo: Extinction and recovery patterns of scleractinian corals at the Cretaceous-Tertiary boundary, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 214, 195-223, 2004.

Marshall, C. R., and P. D. Ward: Sudden and gradual molluscan extinctions in the latest Cretaceous of western European Tethys, *Science*, 274, 1360-1363, 1996.

Marubini, F., C. Ferrier-Pagès, P. Furla, and D. Allemand: Coral calcification responds to seawater acidification: a working hypothesis towards a physiological mechanism, *Coral Reefs*, doi: 10.1007/s00338-008-0375-6, 2008.

Paul, C. R. C.: Interpreting bioevents: What exactly did happen to planktonic foraminifers across the Cretaceous-Tertiary boundary?, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 224, 291-310, 2005.

Payan, P., J. P. Girard, and B. Ciapa: Mechanisms regulating intracellular pH in sea urchin eggs, *Developmental Biology*, 100, 29-38, 1983.

Raup, D. M., and D. Jablonski: Geography of End-Cretaceous marine bivalve extinctions, *Science*, 260, 971-973, 1993.

Sepkoski, J. J., Jr. 1996. Patterns of Phanerozoic extinction: a perspective from global data bases. Pp. 35-51. In O. H. Walliser, ed. *Global Events and Event Stratigraphy in the Phanerozoic*. Springer, Berlin.

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5, S1165–S1170, 2008

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Sheehan, P. M.: The Late Ordovician mass extinction, *Annual Review of Earth & Planetary Sciences*, 29, 331-364, 2001.

Smith, A. B., and C. H. Jeffery: Selectivity of extinction among sea urchins at the end of the Cretaceous period, *Nature*, 392, 69-71, 1998.

Ward, P. D., J. W. Haggart, E. S. Carter, D. Wilbur, H. W. Tipper, and T. Evans: Sudden productivity collapse associated with the Triassic-Jurassic boundary mass extinction, *Science*, 292, 1148-1151, 2001.

Interactive comment on *Biogeosciences Discuss.*, 5, 2401, 2008.

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5, S1165–S1170, 2008

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