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Solid Earth Discussions

Interactive comment on "The Eons of Chaos and Hades" *by* C. Goldblatt et al.

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We thank Nick Arndt for a constructive review of our manuscript. We respond to each section of the review (included in italics) below.

In this short paper the authors propose the name Chaotian for the period between the origin of the Solar System and the Moon-forming impact, and suggest a series of names for subdivisions of the Hadean, the period of geological time between the formation of the Earth and the start of the Archean. As someone who has always had some difficulty in remembering the name of the period between the Ordovician and the Devonian, and is totally at sea when my colleagues in Grenoble start speaking of the Hauterivian or the Cenomanian, I look upon this suggestion with some unease. The justification for introducing the names is that they would introduce some rigour into the terminology used to describe the early history of our planet. Perhaps so, but for

me, to speak of the "period before the Moon-forming event" is far more informative and clear than the use of terms such as the Eochaotian or Nephelean. Similarly, I prefer "early Proterozoic" to Paleoproterozoic and blanch at the idea that the Hadean should be subdivided into the Hephaestean, Jacobian, Canadian, Procrustean and Acastan.

We understand the general argument that names do clutter the numbers – however, for the same reason that people self-identify by names not social security numbers, we argue that the standard geological practise of naming periods is indeed helpful – names are equivalent to a rapid 'shorthand' for specialists, quickly placing the rock or event in the right setting. Just as Cretaceous specialists find the term Cenomanian extremely helpful, so specialists in the early history of the solar system and the Hadean Earth will find it much easier to use names rather than numerical date ranges.

The usages Neo and Paleo are standardised.

I accept, grudgingly, that formal names are required for Phanerozoic systems or periods. The limit between the Cretaceous and Tertiary can be identified in outcrop, labelled with a "golden spike", dated accurately and shown to coincide with a major geological event. The same cannot be done with the subdivisions of the Precambrian, even for the Archean and Proterozoic where the rock record in more or less complete. And for the Hadean, any stratigraphic subdivision must remain nebulous. Flagging a 4.3 Ga zircon in ANU's Jack Hills collection does not have the same weight as the stratigraphers' Global Boundary Stratotype and Point.

We agree that defining boundaries in Earth history at clear events in Earth history is greatly preferable. Nisbet, one of our authors, has argued strongly for this point, against the preferred usage of 'round numbers' in defining the Archean-Proterozoic boundary.

We argue in the paper that the two Eon boundaries discussed should be defined by impacts (as the Cretaceous and Tertiary (Paleogene) boundary is): the Moon forming impact for the Chaotian-Hadean boundary and the end of the Late Heavy Bombardment for the Hadean-Archean boundary.

We have added text to emphasise this in the manuscript (bold here): The Late Heavy Bombardment seems intrinsically Hadean and the final impact of this would be the logical choice to terminate the Hadean Zahnle et al. (2007), **being a clearly identifiable event and** heralding the start of the continually habitable period.

Where boundaries are presently at fixed times, we hope that increased knowledge in the future will lead to them being tied to specific events. Returning to the example of the Archean-Proterozoic transition, co-author Zahnle envisions that this will come to be defined at the end of widespread Mass Independent Fractionation in Sulphur isotopes (MIF-S), which is seen globally and represents the end of the reducing conditions which characterised the Archean. Likewise, we hope that future scholars will be able to better define the boundaries of proposed infra-Hadean, similar to the manner in which Phanerozoic boundary definitions have evolved.

We have added the following text to the manuscript: **Whilst we have used ages to demarcate periods here, we are firmly of the belief that boundaries should correspond to specific events in Earth's history (as previously expressed by Nisbet, 1991). We hope that future work will tie our proposed boundaries to specific events, or modify the periods to be bounded by key events yet to become apparent.**

The manuscript does provide a brief clear account of the early evolution of the Earth and this is useful. As a terminology-challenged petrologist, I do not welcome the introduction of a new set of names, but I recognise that many other geologists like this sort of thing. I therefore recommend that the manuscript be published in Solid Earth, to stimulate discussion about this important part of Earth history.

We thank the reviewer for recommending publication despite his philosophical objections! Uptake by the community will be the true test of our proposals, of course.

Page2, line 2: Does the Moon-forming impact represent the"true birth of Earth"? It was indeed the major event in our Earth's infancy, but I would argue that the planet was

born about the time it reached nearly its present size and the core segregated, some 30-50 m.y. earlier than Thea's impact with Tellus (the authors will note that I am not totally refractory and do accept some of their new names).

It is the birth of the Earth in the sense of anything that could conceivably retain a geological record on its surface. It is clearly the birth of the Earth-Moon system, and the existence of the Moon stabilises Earth's obliquity (which would otherwise vary between 0 and 85deg over timescales of tens of millions of years). Had they not collided, Theia and Tellus could have remained to this day and we would not live on Earth.

Page 50, line 17: The interpretation that the"amphibolites" of the Nuvvuagittuq region are $\sim$4.3 Ga old is not universally accepted (see, for example, Andreasen and Sharma, 2009). Another possibility is that the Nd isotopic data record the existence of a older enriched source of these rocks, not their crystallization age; just in the way that the Hf isotope compositions of the oldest zircons record the existence of a source that acquired its enriched character about 4.5 Ga ago (Blichert-Toft et al, 2008). The evidence of old rock recorded by the Nuvvuagittuq amphibolites is not very much more solid than the negative epsilon Nd or the $>$4 Ga zircons in the Acasta gneiss, or the very existence of the $>$4 Ga Jack Hills zircons. This example well illustrates the perils of assigning ages, and names, to periods in the earliest part of Earth history.

We understand that these claims of antiquity can be disputed, but they are good candidates. It is commonly the case in Phanerozoic stratigraphy that definitions move localities: for example, none of the GSSPs for the Cambrian, Ordovician or Devonian are in the regions where the systems were initially described and take their names. Likewise, Quaternary and Tertiary record a long-forgotten early fourfold division of time.

References

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Interactive comment on Solid Earth Discuss., 1, 47, 2009.