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Interactive comment on "Towards adaptable, interactive and quantitative paleogeographic maps" *by* N. Wright et al.

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We would like to thank the referees, J. Golonka, S. Peters, and C. Scotese, for their comments on our manuscript "Towards adaptable, interactive and quantitative paleogeographic maps". We are implementing changes to our manuscript, based on the comments below.

Comment (Golonka): I do not like the "50 million years approach to the presentation of paleogeographic maps.

Comment (Peters): I found the age-to-age description somewhat tedious. That doesn't mean it isn't important or worth including, but it does mean that if there are points buried in there that you think are really important, they need to be clearly exposed in

some way.

Comment (Scotese): The chronological review is desultory, incomplete and mostly irrelevant. You are just restating what the Australian paleogeographic maps show. Why is this relevant?

Response: The paleogeographic map time slices are being updated to intervals based on time slices described by Golonka et al. (2006) and to represent significant intervals throughout the Phanerozoic. The maps were included to demonstrate the coverage and correlation of the fossil data from the Paleobiology Database with the Paleogeographic Atlas.

Comment (G): I do not understand the choice of choice of the time slices for detailed evaluation. On one hand short slice like Emsian, on the other hand the whole Cretaceous.

Response: We chose time intervals that had significant shifts in inundation patterns that have been also captured in the fossil data in order to improve, refine or groundtruth the paleogeographic maps. The Early Devonian was a time of rapid change on the eastern Australian margin, and this was evident in the inundation patterns in central Victoria and southeast New South Wales. The Cretaceous inundation was a longer wavelength event, with subsidence induced by sinking slabs in the mantle, leading to slower onset and retreat of inundation. As a result, the temporal range for this event was great in order to capture the pre- and post- inundation conditions on the continent.

Comment (P): How do you allow for error in the coordinates and ages of fossil collections?

Response: This is a fair comment, and it is a concern for all studies that utilise databases. Ideally, the data density should be greater to reduce the risk and effect of incorrectly entered data points. However, on the large regional scales at which this study is being undertaken, we hope that such errors would not significantly affect the

interpretation. If the database contained more data density, then we would have considered looking at finer local scales – but this would have relied on too few data points.

Comment (P): The Paleobiology Database is open access, but not really open source. The code that does all of the logic of things like taxonomy and age assignments is largely hidden and in the mind of John Alroy (and similarly capable interpreters of Perl written with best- practices only as a good notion in mind.)

Response: We agree with this statement, and are revising the text to acknowledge that the Paleobiology Database is open access rather than open source.

Comment (P): On page 9614 you say that the existing reconstructions didn't draw on fossil data. Really? What did they draw on then? I always though most paleogeographic reconstructions past the point of seafloor-constraints involved everything possible.

Response: The Paleogeographic Atlas of Australia relies largely on available stratigraphic well data, outcrops, and other observations. Therefore, fossil data from the Paleobiology Database provides an alternative source of paleoenvironments in Australia and the discrepancy between the Palaeogeographic Atlas of Australia and Paleobiology Database may be used to expand on the currently inferred paleogeography.

Comment (P): On pg. 9618 you say, if I may translate into something more succinct, that it is difficult to identify the meaning of an absence in fossil data. Forgive the advocacy, but this is one of the reasons why macrostratigraphy is so useful. It is based just as much on the absences as the presences. In my view, macrostratigraphic data would be much, much more useful for constraining most elements of paleogeography for this reason (and others).

Response: We have since incorporated stratigraphic data into the case studies, based on the stratigraphic unit associated with the fossil (found in the metadata from the Paleobiology Database) and the lithology and inferred paleoenvironment described by

published research.

Comment (P): Related to above, on page 9619 why do you say global coverage is poor in Carboniferous? What is the "denominator" here?

Response: The number of fossil collections observed in the Carboniferous is less than the Devonian (and a lot smaller than the Permian), which can easily be observed by using the Paleobiology Database analyse function or by analysing the fossil data using ArcGIS or QGIS. Based on the data we downloaded from the Paleobiology Database in October 2011, in the Mid Devonian (at 400 Ma), 1508 fossil points are observed globally, whilst in the Early Carboniferous (at 348 Ma) only 884 fossil points are observed, and during the Late Carboniferous (at 302 Ma), 1397 fossil points are observed. The Late Devonian extinction event may also be responsible for the reduced fossil coverage in the Carboniferous.

Comment (P): Fig. 5. What does it mean that this dataset "sufficiently represents" Phanerozoic biogeography

Response: There are two components to this – one, that we assume the fossil record in the Paleobiology Database is a sufficient record of environmental and biotic change as demonstrated by Hannisdal and Peters (2011), and two, that based on the (temporal) ranges of the fossil collections, they cover the entire Phanerozoic. Of course, the data density at any particular time is lower than the cumulative total fossil collections, but our objective was to expand on, validate and improve the paleogeography where possible and where fossils could be used to determine the paleo-environment. This was particularly the case of basins in eastern Australia, as the cratonic interior does not contain any Phanerozoic fossils.

Comment (P): Fig 10. Isn't it possible that the distribution of collections is a surface exposure vs. subsurface issue? The vast majority of fossil collections in the PaleoDB come from surface outcrops. Again, this is a reason why Macrostrat-type data are so useful. They includes both surface and subsurface data, as well as data that help

constrain some geodynamic things (like sediment thickness). It sure would be great to have such data for Australia!

Response: We entirely agree that macrostratigraphic data would significantly enhance this study, and others in the future. Having access to such data would add another layer against which interpretations can be improved and validated. Unfortunately building such a database was well beyond the scope of this study, and we hope that Macrostrat will be extended to cover Australia – and perhaps incorporate well logs from Geoscience Australia. We have already started thinking about how to incorporate and link to such databases using GPlates.

Comment (S): The title should be changed to something like, "Ground-truthing Australian paleogeographic maps using fossil information from the Paleobiology Database".

Response: We are changing the title, to better reflect the aim and content of the manuscript.

Comment (S): The section on Greater India should be dropped. Greater India This section seems like it belongs in another paper. It has nothing to do with the Paleobiology database/Australian atlas. Yes, I agree that paleogeography can be used to test plate models. It is interesting but not relevant to this paper

Response: We are removing this section, as it requires more detailed analysis, and probably a separate study.

Comment (S): All uses of the terms "paleobiology" and "paleobiogeography" should be changed to a more appropriate descriptor. (see below for suggestions).... The terms paleobiology and paleobiogeography should be deleted from the text. They mean something very different from what the authors are describing.

Response: Thankyou for the clarifications and suggestions. The terms paleobiogeography, biogeography, paleobiology, are being updated, based upon Scotese's sugges-

tions.

Comment (S): The authors should be congratulated for recognizing that the information in the Paleobiology database can be used to test and improve existing paleogeographic maps, but should also recognize that the PBDB cannot be used to make a paleogeographic map from scratch.

Response: We agree with this statement; if a paleogeographic map were made from scratch based solely from Paleobiology Database data, it would be very sparse and require a lot of interpolation. The text is being updated to emphasise this point. Our approach builds on expanding existing paleogeographic maps using more data that is contained in the Paleobiology Database.

Comment (S): As far as I know there are no "dynamic maps". I.e. which constantly change and are updated with the inflow of new data. It is unlikely that there will be any "dynamic paleogeographic maps" any time soon, because a paleogeographic map is a highly interpreted creation. It is based incomplete data, is strongly dependent on time dependent contingencies, and like all maps is simply a visual hypothesis that needs be tested with additional data. I agree that the best paleogeographic maps are made, maintained and updated using a technology that combines mapping software and databases. However, this is not GPLATES but rather a GIS (Geographic Information System). This is what I use. I find it odd that the authors do not even mention GIS technology, which is the obvious solution to the problem of "static maps". And yes, there is GIS software that also reconstructs plates using the same data and algorithms as GPLATES. ..... Again, there is a misconception about how high quality paleogeographic maps are made. GIS is the best solution because it includes all the positive attributes the authors tout: dynamic, easily updated, and easily changed. The authors need to mention this option.

Response: We agree that paleogeographic maps are dependent on the interpretation of available data and it is not feasible (or currently practical) to create maps that con-

stantly change based on new or updated data. However our approach allows users to observe inconsistent paleoenvironments and adjust existing paleogeographic maps, and more importantly, without any constraint to an author's plate motion model. GIS software, such as ArcGIS or QGIS, is also important in the creation of paleogeographic maps. GPlates has components of GIS, but is advantageous due to the combined spatio- temporal approach of reconstructing data through time. Geometries, such as points that represent fossils, in GPlates contain all the shapefile metadata, which is reconstructed with the geometry – meaning that we do not lose the "information" component in our reconstructions. At any reconstruction, the user can query or export fossil locations and all their associated attributes.

Comment (S): The Emsian example is in error and should be fixed or removed (see comments below)... The map shown is Devonian (4), which according to the Australian Paleo- geographic Atlas represents a very short interval (less than 1 million years) at the end of the Emsian (398). The latest Emsian map (probably a regression) does indeed lack a marine seaway. The actual Emsian map (Devonian 3; 407 - 398 Ma) does show the seaway and is nearly identical to their map "C". Another words, fossil localities are in excellent agreement with the actual Emsian map. Also, the date shown on the figure (395 Ma) is Eifelian, not Emsian.

Response: We believe this confusion may have arisen from time-scale issues, since the Emsian time range varies based on the time scale. We have converted the timesteps to a common timescale to address the confusion. Indeed, we had reconstructed the Emsian timestep but due to slight timescale offsets in the original files, the Emsian coincided with the 395 Ma absolute time. This is no longer the case, and the absolute age corresponds better with the Stage boundaries.

Comment (S): The citation for Langford, 2001 should be double-checked... A key citation (the source of the paleogeographic maps) is probably incorrect. I spoke with Rob Langford and he believes the citation refers only to his Cenozoic Atlas. The proper citation should probably be "Totterdell, J, 2002. XXXXXXXXX"- which is how the on-line

database is credited.

Response: The Geoscience Australia website was checked again, and the only references that could be observed were a list for the individual atlases, and an "Authors" list, which we have currently used (found at the bottom of http://www.ga.gov.au/meta/ANZCW0703003727.html). We have since obtained suitable reference from Geoscience Australia.

Comment (S): Also the plate model, which is provided in the Supplement, is credited as Golonka, 2007. The model that is used is clearly the PALEOMAP Project plate model circa 1995. In the text Golonka does cites the source of the plate model as Scotese (2004) but like all plate models, the credit tends to get lost (especially when all the comment fields are deleted!!).

Response: Unfortunately, there is no published plate model from the PALEOMAP Project that we can attribute a reference to. The reference was credited to Golonka (2007) due to the availability of a plate motion model file. However, we are including a note in the text to acknowledge the collaborative work between Golonka (2007) and various aspects of the PALEOMAP Project.

Comment (S): Relative plate motions cannot be determined by "commonalities in APW paths". You can only determine fixed relative positions. In any event it is to a solution to the longitude problem.

Response: This is a fair point, and is being clarified. What we meant was that the tectonic unity of two continental blocks can be determined by looking for the same pattern in the APW paths. However, APW paths can only be used to infer paleo-latitude and not paleo- longitude.

References

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