

General Comments:

This is an interesting paper that does an excellent job combining two disjoint data sets (plate tectonic models & paleogeography) into a cohesive synthesis. The resulting discussion of the relationship of continental flooding to sea level and to the changing ratio of strontium isotopes in the oceans through time is clearly presented. All the figures are readable and well done. The writing is patchy, but I have made numerous suggestions for the authors.

This study had four principle objectives: 1) to describe the process by which the paleogeography (Golonka) developed for one plate tectonic model (Scotese) could be reverse engineered and plotted on an alternate plate tectonic model (Matthews), 2) to improve the Golonka paleogeography by adding additional constraints from the Paleobiology Database, 3) to compare the resulting estimates of continental flooding through time with published sea level curves, and finally, 4) to explain the changing ratio of strontium isotopes in the ocean with the observed patterns of continental growth and emergence.

Each of these objectives was successfully met, to varying degrees.

Objective 1: The new set of paleogeographic maps produced in this paper, clearly demonstrates that it is possible to transfer the paleogeographic information from one set of maps (Golonka, 2006) to another set (Matthews, 2016) – as long as plate tectonic models are available for both sets of maps. However, the methodology cannot be considered to be a universal solution. As pointed out by the authors, the paleogeography and plate models are inextricably joined, and moving the paleogeography from one plate model to another plate model inevitably results in gaps and overlaps (see Figure 3c). Unfortunately this will always be the case. It will always be necessary to laboriously “hand edit” any attempt to transfer the paleogeography from one plate model to another.

Objective 2: There are several issues here that need to be discussed. My first major point is that I am not convinced that the “revised” coastlines are a significant improvement over the original coastlines. Though, I agree that the addition of information from the Paleobiology database can, in some areas, improve the location of the coastlines, it is not clear to me that the overall result is an improvement or merely a slight modification.

There are two reasons for my skepticism. Firstly, I do not know what original data was used to draw the coastlines. Therefore I do not know how much “weight” to give the Paleobiology data with regard to the original data. For example, if the original coastline is based on a dozens of coastline estimates from a variety of sources, then a few additional data points from the PBDB should not be given much weight. Conversely, if the original coastline position was an educated guess based on little or no data, then the extra information from the PBDB would be very welcomed. So, simply, we don’t if the changes are an improvement or not.

The second reason for doubting that any improvement has been made is to consider what the coastline drawn on the original maps actually represents. In this case, I believe the error lies with the mapmaker, not the analysis.

The 24 maps in this study cover ~400 million years. That means, on average, that each map represents an interval of 17 million years. It seems very unlikely that the coastline would have

remained in one place for 17 million years. A more reasonable representation of the “coastline” for this long interval would have been to show it as a “zone” that was alternately marine or terrestrial. (see my Figure 1).

One way to simulate this would have been to erect a 250- 500 km buffer around the coastline, and then test only the points that lied outside of the buffer. I am not suggesting that the authors do this, but rather I am suggesting that it is likely that the “discrepancies” they point out, may in fact, be perfectly OK, given the changing location of the coastline through time.

In this regard, I think the manuscript would be improved if the author’s pointed out this possibility and changed their wording so that it sounds less pejorative (i.e. You made mistake and now I’m going to fix it.)

In fact what would be more valuable if the authors listed all the marine data points that plotted on mountain ranges or more than 500 km from the proposed coastlines, or conversely, terrestrial deposits that plotted in the deep sea (off the edges of the continents). In these cases, changes to the paleogeographic maps should certainly be made!

Objective 3: Everything here looks pretty good, however there was a little graphical confusion that needs to be fixed. It is hard to argue against a positive correlation between sea level rise and continental flooding, and I am happy to see that in Figure 9A both trends track each other well. However, it is not clear which units (y-axis) apply to which curve. This should be cleared up in the Figure caption. More problematic, however, is that the fact that the figure implies that these two very different units scale together. i.e. 40% flooding = 160m rise in sea level. This is certainly not true. The cleanest solution would be to separate these two graphs, but place them one above the other.

Objective 4. The same objection raised to Figure 9a also applies to 9b. It may be necessary to separate this figure into two diagrams.

Additional General Comments:

The Methods Section consistently misuses verb tense. Lines 115 – 334. You are describing actions that you did in the past. You must use the past tense, not the present tense e.g. “They are first georeferenced” should be “They were first georeferenced.” Review all verb tenses in this section and correct.

There is a confused an improper use of the terms “fossil” and “paleobiology”. No fossils were used in this paper, only fossil collections that revealed paleoenvironmental conditions, i.e., marine or terrestrial.

When listing ranges of dates, “Ma” should appear after each date if the dates are separated by a “and” or “to”, e.g. 402 Ma and 2 Ma or 402 Ma to 2 Ma. This is not necessary if the dates are separated by a dash, as in 402-2 Ma.

Other specific comments regarding the text, figures or tables are given in the following section.

Specific Comments by line:

016 Delete “time-dependent global” and “Several”

018 The phrase “static maps with varying temporal resolution and fixed spatial resolution” is not clear and seems redundant and should be rewritten. Aren’t all maps “static” and have a fixed “spatial resolution”, i.e. “scale”. So?

020 Though the authors were successful in “reverse engineering” the Golonka maps, the workflow they [produced is not a general or universal solution. Because of the idiosyncrasies of various plate tectonic reconstructions, each reverse engineered set of maps requires extensive hand editing to fix the resulting gaps and overlaps. This will always be true. So the claim that this new workflow fixes that problem and is a universal solution is incorrect and therefore the claim must be withdrawn or modified.

022 The sentence, “Published paleogeographic . . . datasets.” is not informative and should be deleted.

023 “fossil data” to “paleoenvironmental data”.

023 I am not convinced that the maps were improved. See my comment above. There are some methodology problems here - both in the map making and analysis. The best I think you can say is that “the maps were modified to be more consistent with the paleoenvironmental data from the Paleobiology database.” This statement does not imply that the resulting maps are “better”. (I know this seems like nit-picking, but it actually is an important point!)

039 A definition of what you mean by “paleogeography” might be appropriate here. I favor this definition, “paleogeographic maps describe the ancient distribution of highlands, lowlands, shallow seas, and deep ocean basins”. Of the list of examples, that would disqualify Scotese (2004), but Scotese (2001 and 2004) could be substituted (see list references cited at end of review).

043 Here we go with that static .. fixed spatial resolution “ business again. Why don’t you just say that it is difficult to convert the maps into a digital format because of the varying map projection, different time intervals represented by the maps, and the different plate models that underlie the paleogeographic reconstructions. I agree that there is great power to having the paleogeographic data in a digital format so you can . . . (examples). Yes, this is a worthwhile goal.

052 use “these issues”

054 not “any plate model” but a “different plate model”. Your workflow is not a universal solution. It is likely that any change in the plate model will create new gaps and overlap that will have to be fixed by hand.

055 Try rewriting this sentence without the jargon. “The first step was . . . “

058 You didn’t “reverse-engineer the global maps” (whatever that means). You “restored the ancient paleogeographic boundaries back to their modern coordinates by applying the inverse of the rotation that was used to make the ancient reconstruction.” More words, but more clear.

060 -062 How about saying this, “Subsequently, we used information about marine and terrestrial paleoenvironments available from the Paleobiology Database to modify the location of the paleocoastlines.”

068 “modeled” should be “modeled”

073 “paleoenvironmental data” not “paleontological data”

077 see my comments about Table 1.

084 change “a plate tectonic model” to “a mysterious plate tectonic model “ - just kidding!

089 not “reverse-engineer”, but “ restore these paleogeographies to their present-day coordinates”.

091 in Figure 2 of this review I show that the plate model is identical to Scotese (1997) that was published in Scotese (2004). So the sentence should read, “are based on Scotese (1997, 2004)”. My plate models have been widely available – mostly through the paleomapping programs I have written (with students) – Terra Mobilis, PaleoMap-PC, PointTracker, & PaleoGIS. Jan probably obtained a copy from me directly, or by using one of my programs. In either case, I deserve credit for the plate model (but not the paleogeography).

106 “fossil collections” rather than “documented fossils”

116 This is an important sentence. It must be clear. Try, “The methodology can divided into three steps: 1) the original paleogeographic boundaries were restored to present-day coordinates by applying the inverse of the rotations used to make the reconstruction, 2) these restored boundaries were then rotated to new locations using the plate tectonic model of Matthews et al. (2016), finally, 3) the location of the paleocoastlines were adjusted using paleoenvironmental data from the Paleobiology database.”

117 Figure 2 illustrates the generalized workflow.

126 “to refine the rotations and ensure that the paleogeographic boundaries are restored accurately to their present-day locations.”

141 Emphasize how tedious and labor intensive this procedure is. “The gaps and overlaps were fixed, feature by feature, map by map, by extending or modifying the outlines of each mismatched polygon in order to make the boundaries connect in a similar fashion to the original paleogeographies.”

151 Try “Once the gaps and overlaps were fixed, the reconstructed paleocoastlines were compared with the data from the PaleoBiology Database that described the marine and terrestrial environments of the fossil collections. These comparisons were aimed at indentifying the differences between the mapped paleocoastlines and the marine and terrestrial environments in order to modify the location of the paleocoastlines.”

155 change “Only the fossils” to “Only the fossil collections”

157 change “fossils” to “collections” and “Fossils” to “Fossil collections”

161-165 The sentence starting with “Alternatively . . .” and everything after it, should be deleted. It is unnecessary. Makes things unnecessarily complex.

169 “collections were then attached” - delete “motion”

170 Try, “Subsequently, a point-in-polygon test was used to determine whether the indicated terrestrial or marine fossil collection lied within the appropriate marine or terrestrial paleogeographic polygon. The results of these tests is discussed in the following section. (delete the rest of this paragraph).

177-178. “In the next step, we modified the location of the paleocoastlines based on the differences between the paleoenvironments indicated by the fossil collections and the mapped paleogeography. Figures 4 & 5 illustrate how the paleocoastlines were modified. “

184 “. . . taken into account. (3) The boundaries . . .”

192 “to maximize the use of the paleoenvironmental information from the fossil collection to improve . . .”

205 “ when using the fossil collections. . .”

208 “deceptive fossils, however, are rare.”

211 “4.1 Paleoenvironmental Tests” - no Paleobiology used here.

210 -254 I still think this “consistency/inconsistency ratio ” is somewhat dubious due to the changing location of the coastline (see previous discussion). Maybe if it were couched in terms of a “match ratio” , or “mixing ratio” rather than an “inconsistency ratio”. A high mixing ratio (mixing of marine and terrestrial data) would indicate a widely fluctuating coastline. A low mixing ration would indicate relatively stable shorelines.

Again, what should be flagged as anomalous are marine data points far removed inland from coastlines (>500 km) or terrestrial data points far removed, oceanward of coastlines. It seems nearly pointless to flag contrary indications that lie adjacent to the coastline.

254 “scarce, the fossil collections were of limited . .”

261 “Methods”

264-267 Rewrite this sentence.

281-287 Rewrite, simplify, clarify. “380-285,81-58, and 37-2 Ma” should be “30-285 Ma, 81-58 Ma, and 37-2 Ma”

313 NO. The sea level curves of Haq et al. 1987 & are not inferred from the flooding ratios. They have a completely separate derivation. I would delete this sentence.

310 – 323 These values are in good agreement with the flooding curve I have independently produced.

326 A similar pattern of changing areas was published by Worsley et al (1984), Fig. 7.

335 “402 Ma to 2 Ma”

343-345 I don’t understand what you’re trying to say here. Don’t you mean “emerged”, not “submerged”?.

368 “utility” rather than “flexibility”

372 “variable” rather than “flexible”

375 “using paleoenvironmental data obtained from fossil collections”

397 Please include an acknowledgement to my help with the editing.

Comments about Tables

Table 1

Nearly all of the Sloss Sequence designations are incorrect. See Table 1 Revisions.

Also the timescale for the maps is not the latest ICS timescale (2012). This means the ages may be off by as much as 4-6 million years.

Table 2 - OK

Comments about Figures

Fig 1 I would arrange with oldest on bottom to match the timescale on the left.

Fig 2 change “Reverse Engineer” to “Restore to Present-day”

change “Fix gaps” to “Fix gaps and overlaps”

Fig 3 Excellent Figure!

Fig 4 Nicely done, very clear.

Fig 5 Very clear – though I am not sure the changes are significant.

Fig 6 I would change it to “Match Ratio”. Otherwise clear.

Fig 7 These are a nice set of maps. Well done. I think the revised coastlines are fine, however the continental margins seem cartoonish and extend far beyond the COB. The size and placement of the mountains through time are very inconsistent.

Fig 8 Clear.

Fig 9 Potentially misleading. Both 9a & 9b should be separate diagrams because the y-axis values are different, and not equivalent. See text comments for elaboration.

Comments about References Cited

In good shape, only a few things

41 Blakey, 2008, is Blakey, 2003 in References

95 Domeier and Torsvik, 2014 is missing, but there is a Domeier, 2016 that is not cited in the text.

311 & 312 There is no Haq et al., 2012 in the References; Haq et al, 2008?

Comments about Supplementary Materials

Good to have a copy of Golonka (2006) included. It would have been nice to have the rotation model used by Golonka included as well. The link to the Supplement of Golonka (2007) is no longer active.

I compared some of Golonka's original maps to the updated paleogeographies. In some cases I was not able to see any of the modifications (see Figure 3). It would be good to have a complete set of maps with the red and green symbols plotted as in Figures 4 & 5. That way we could see what was changed.

When I loaded the Paleobiology data points in Gplates, I could not distinguish the "marine" from the "terrestrial" data points. The only attributes that I could discern were "plateid" and "end and start" times. The marine data and the terrestrial data should be in separate files.

References Cited in this Review

Scotese, C.R. Continental Drift Flip Book, 7th edition, PALEOMAP Project, Department of Geology, University of Texas at Arlington, Texas, 80 pp.

Scotese, C.R., 2001. Atlas of Earth History, Volume 1, Paleogeography, PALEOMAP Project, Arlington, Texas, 52 pp. https://www.researchgate.net/publication/264741875_Atlas_of_Earth_History

Scotese, C.R., 2004a. Cenozoic and Mesozoic Paleogeography: Changing Terrestrial Biogeographic Pathways, in *Frontiers of Biogeography: New Directions in the Geography of Nature*, M.V. Lomolino and L.R. Heaney, (editors), Sinauer Associates, Inc., Sunderland, Massachusetts, p. 1-26.

Scotese, C.R., 2004b. A continental drift flipbook, *Journal of Geology*, v. 112, issue 6, p. 729-741.

Worsley, T. R., Moore, T. L., Fraticelli, C. M., and Scotese, C.R., 1994. Phanerozoic CO₂ levels and global temperatures inferred from changing paleogeography, in Klein, George D., (editor), *Pangea; paleoclimate, tectonics, and sedimentation during accretion, zenith and breakup of a supercontinent*. Special Paper Geological Society of America, 288, p. 57-73, Boulder, CO.