

## ***Interactive comment on “The Cretaceous and Cenozoic tectonic evolution of Southeast Asia” by S. Zahirovic et al.***

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Received and published: 27 September 2013

### **General Comments**

Zahirovic et al. present a new plate reconstruction of SE Asia and Australia from 155 Ma to the present day based on their reassessment of previously-published data and tectonic models. The authors should be congratulated in synthesising such a vast amount of information from the literature regarding the geology, geochronology, geochemistry, palaeontology, sedimentology, palaeomagnetic history, and present-day geophysics of this tectonically-complex region. This new reconstruction differs in several ways from previously-published plate reconstructions for the region (i.e. Metcalfe, 2011; Hall, 2012; Morley, 2012), the main differences being the accommodation of northward Indian movement purely by rifting as opposed to invoking displacement

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along the I-A transform, and a New Guinean origin for W Sulawesi, E Java, Mangkalihat, SW Borneo, and E Borneo as opposed them being derived from the NW Australian margin.

There is no doubt that this task has been a serious undertaking, and the authors have demonstrated that they have been thorough in their approach, especially when considering the vast and geologically-diverse region involved. It is therefore frustrating that often the message is obscured by the poor clarity of the text. The discussion is definitely the better written part of the paper, in which complex ideas are carefully and often clearly explained, for instance in section 4.2. It would be of great benefit to the readability of the paper as a whole if the earlier sections, especially the introduction and methodology section, were written to the same standard. It is a shame that sometimes ambiguous and overly-long sentences detract from the intended message. Also, the tense often confusingly switches between present and past, e.g. on page 1367 – past tense ('experienced extension'; line 3) switches to present tense ('Extension also propagates'; line 13). I found it more readable when the past tense was used to describe proposed past events, such as was used in the conclusions. Regarding these issues, I've made a list below of parts that I felt were ambiguous or awkward to read. I hope I'm not being too picky, but, for me and maybe others, this would greatly improve the readability of the text. Aside from these points, the paper still provides a very interesting discussion of tectonic models for SE Asia.

My main question about this new plate reconstruction is if there is any geological evidence for W Sulawesi, E Java, Mangkalihat, and E Borneo having been derived from New Guinea and not NW Australia. In the discussion, no convincing justification is presented for this decision, and an alternative suggestion is given in figure 12 and mentioned briefly in the text for them indeed having a NW Australian origin. Following on from this, I'd ask the authors to explain why Seram and eastern Sulawesi, comprising the Sula Spur, are shown to appear from nowhere at 80 Ma in the reconstructions. If the Argo and Banda blocks were rifted from the NW Australian margin, as proposed

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by Hall (2012), this could explain how the Banda Embayment was formed and would solve this problem. Another concern is that on a few occasions little justification is given for preferring one previously-published model over another. It would also benefit the paper if more new ideas were proposed and/or discussed in addition to the previous models. And at times, it seemed as though preference was given to geometry rather than geology. It should also be pointed out that no new geological or geophysical data is reported, but I appreciate that it is beyond the scope of the study to have done so, and the authors clearly state that the paper is a synthesis of previous work.

My conclusion is that the new plate model presented by Zahirovic et al. will certainly further stimulate discussion over such a tectonically-complex region, which can only be a good thing, irrespective of some personal disagreements with certain aspects of the reconstruction. The paper also provides a valuable synthesis of such a huge amount of literature. Therefore, I recommend that the paper should be considered for publication, subject to the revisions outlined below.

### Specific Comments

#### Page Line

1336 9-13 The sentence beginning 'We propose a scenario...' is confusingly written – it is not immediately clear what is rifting from Gondwana or which subduction zone is providing the slab pull.

1337 5 It is not clear what you mean by 'continuously closing plate boundaries'.

1337 23 Maybe you need to explain what you mean by 'Tethyan conveyors'

1338 14 It's not clear what 'affinity' is referring to – affinity to continental basement?

1338 18 It sounds like you are referring to a remnant of spreading (which makes no sense), not the Jurassic oceanic crust produced by spreading.

1338 21 'results in uncertain origins' sounds a bit strange

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1338 24 It's not clear what you mean by 'pre-breakup fits'

1339 1 'submerged and remote': I assume you're implying that much of Sundaland is either below sea level, poorly-exposed, or difficult to access.

1339 18 wrong tense: how about 'in order that our model may be tested and improved'?

1339 20 Methodology Section: As the reader, I was not made absolutely clear of the criteria you used to construct your model. It is often ambiguous what you intend to say. For example, the sentence 'Proxies of convergence...and orogenies.' requires the reader to make too many assumptions to arrive at the message you intend. I would recommend that you work on improving the clarity of this section, especially as it should provide the fundamental basis for your plate reconstruction.

1339 21 'geological data' sounds a bit vague... maybe worth elaborating...?

1339 22 Why do you equate the time of ophiolite emplacement to its crystallisation age? Also, how can the timing of ophiolite emplacement be used to infer rifting events? Are you referring strictly to obducted ophiolites (Oman-type), or do you also refer to newly-generated oceanic crust and/or exhumed subcontinental mantle rocks?

1339 25 '...collisional events are inferred from...': You imply that high-T metamorphism is diagnostic of collision, yet it may also be achieved by extension.

1339 27 What style of 'ogenies' do you intend?

1340 9 You define certain 'rules' for your model, but what if the Earth did not abide by them all of the time? Is there any scope within your model to test these rules? Would these rules be rigidly upheld if unsupported by field evidence?

1340 11 It's maybe worth defining 'RRR' as 'ridge-ridge-ridge' for those who don't know.

1340 22 Sentence beginning 'Lastly, plate boundary...': What if there was localised extension within an overall convergent setting (or vice versa?).

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1341 5 Again, why does an ophiolite crystallisation age necessarily date its emplacement?

1341 6 Sentence beginning 'Accretion events..': You imply that UHP metamorphism will have always occurred at the onset of collision, why may not be true.

1341 20 Not sure of the use of the word 'interactively'

1342 7 Not sure of the use of the word 'interactively'

1342 17 What are 'block-out lines'? Maybe worth defining.

1343 7 Sentence beginning 'In addition, the...': I found this to be confusing. How can 3-D mantle structure be observed when it's been modelled?

1343 13 'resulting from subducted slabs following Van der Voo et al...': I'm guessing you don't mean this literally!

1344 26 Why is this your preferred scenario?

1345 20 'As the strike...': Is there any field evidence to support this?

1345 29 '...we invoke the separation...': Why?

1346 35 I could not find the Wharton Ridge labelled in figure 1.

1346 27 'Instead, the model of Hall (2012) requires that...': I'm not sure this statement is true. Hall's reconstruction shows only right-lateral slip along the hypothesised I-A transform.

1348 29 'This collision timing': I'm not sure when you are referring to.

1349 2 Sentence beginning 'Rather than invoking...': Your reconstruction shows collision at 80 Ma, not 120-110 Ma. I don't quite see how this ties in with the K-Ar dates you refer to.

1349 3 'this time': which time?

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1351 8 'has been disputed to instead suggest': Do you mean 'reinterpreted to instead suggest'?

1351 16 'we prefer that it accreted to Eurasia in the Triassic': Why do you prefer this model?

1352 9 'The synthesis...': I found your summary of the geochronology results to be slightly ambiguous: Is the 151 Ma age an Ar-Ar result or a K-Ar result? What was dated by Ar-Ar in the Calaguas Ophiolite? Was the Dibut Bay ophiolite dated with Ar-Ar or K-Ar and what do you mean by 'plateau age of amphibolite metamorphism'? What minerals were dated, and how was this related to a metamorphic age?

1352 26 'comparable': in what respect?

1353 7 'We follow the interpretation of Encarnacion...': Why? I'm sure you have good reasons for adopting certain models and rejecting others, but sometimes it's not particularly clear what evidence you've based your decision on. It's maybe worth quickly stating why your preference lies with a certain model to prove that your decision isn't arbitrary.

1354 2 What do you specifically mean by 'developed on'?

1356 9 'In fine tuning...': I found it difficult to grasp what you mean by this sentence.

1357 2 I'm not sure what you mean by the use of the word 'embryonic', also on page 1359, line 14; page 1367, line 12.

1357 11 '...invokes Caroline Plate origin from rollback induced back-arc formation...': I think you could reword this sentence to make it clearer.

1358 4 'We model the origin of...': Why? It would probably be worth providing evidence for this decision.

1358 14 Do you mean 'no seafloor history is preserved' or do you mean that 'no seafloor spreading occurred'?

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1360 23 The Banda Embayment is the term given to the pre-existing D-shaped embayment, bound by the Sula Spur to the north, that once enclosed Jurassic oceanic crust (the Proto Banda Sea). Therefore, the Banda Embayment did not develop by slab rollback as you describe; rather it was rolled back into by the Banda slab.

1361 8 But is there any paleomagnetic evidence to support a northern hemisphere origin? I'm not sure that your criticism is valid.

1364 13 '...and suturing occurred...' Suturing of what?

1366 25 Maybe elaborate on what you mean by 'The dominant tectonic regime was age-coded for present-day basin geometries'.

1367 23 'These compressional regimes continue...': do you mean collision of the Eurasian and Australian plates, not Indian?

1368 19 'but prefer that...': Maybe it's worth reiterating why you prefer this model.

1369 6 '...but we believe it...': Again, what's the evidence for this?

1371 3 'The model proposed by Hall (2011)...': How does your model account for the creation of the Sula Spur? Hall (2011) proposed that the Banda Embayment and Sula Spur were created by the rifting of the Argo and Banda Blocks from the NW Australian margin at 160 Ma, but in your reconstruction, Seram and Northern Sulawesi appear from nowhere at 80 Ma. What's your justification for this?

1374 4 If W Sulawesi, E Java, Mangkalihat, and E Borneo were 'equally likely' to have originated in the Argo Abyssal Plain than northern New Guinea, then why have you chosen to model one origin over the other? 'Equally likely' implies you don't have enough evidence to make a meaningful decision and you're therefore undermining your own argument, especially as this is one of the most significant differences between your plate reconstructions and those previously proposed by Hall (2012), Metcalfe (2011), and Morley (2012).

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1375 14 You give reasons why SW Borneo likely was not derived from NW Australia, but cannot do the same for W Sulawesi or E Java; so why have you chosen to model them having been rifted from New Guinea? What's wrong with NW Australia? If there are good reasons for choosing a New Guinea origin in your reconstruction, the paper does not make them clear. Alternatively, if you are intending to present two possible scenarios, this could also be more clearly stated.

Table 2 'Sarawak Orogeny' and 'Sabah Orogeny' do not make sense as dating methods – how were these orogenies dated?

Figure 4 It looks nice, but I'm not sure how useful this figure is and it's not referred to by the text.

Figure 12 There are no orientations marked on the cross-sections, i.e. NE and SW labels.

Figure 13b I'm sure you've also noticed that this figure has been squashed! I'd suggest you make it as big as possible in the final version of the paper (maybe cut it in half and take up two pages?) as it's very important to what you're proposing and has lots of detail. Why not in the caption refer the reader to your animated plate reconstruction video contained in the supplementary files?

Figure 16 Again, there's no orientation or scale on the cross-sections. Also, it might be worth mentioning how you propose the Proto Molucca slab was over-ridden by the rifting of the Sepik block from New Guinea, as depicted.

### Technical Corrections

Page Line

1337 15 References seem to be listed in a strange order

1337 19 References seem to be listed in a strange order

1337 26 'comprised of' would be more correctly written 'composed of' or 'comprises'?

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1338 17 'gives' should be 'give'  
 1338 27 'Much' should be 'Many'?  
 1339 24 'proxies of' should be 'proxies for'?  
 1340 5 first 'of' should be an 'and': 'the development and evolution of Sundaland'?  
 1343 8 There's a problem with the reference: should be 'Simmons et al. (2009)'  
 1343 18 'Gondwana' should be 'Gondwanan'?  
 1344 1 'originating from' should be 'by'?  
 1345 10 'Gondwana' should be 'Gondwanan'?  
 1348 28 'collide' should be 'collided'  
 1350 22 'indicate' should be 'indicated'  
 1351 26 'by a' should be 'by the'?  
 1352 17 'as a back-arc' should be 'within a back-arc'?  
 1352 19 'wile' should be 'while'  
 1354 2 'Whether' maybe should be 'Whether or not'  
 1354 27 'with the Eurasian' should be 'to the Eurasian'  
 1354 29 'on the margins' should be 'beneath the margins'?  
 1355 3 'can indicate' should be 'may indicate'  
 1355 11 'data is' should be 'data are'  
 1355 15 would be better: 'evidence by Bird (2003) indicates the presence of active subduction zones...'?  
 1356 7 '3 and 1.2' should be '3.0 and 1.2'?

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1356 17 'which is differs' should just be 'which differs'  
 1356 17 'from Hall' should be 'by Hall'  
 1356 18 'histories of' should be 'histories for'?  
 1360 5 'linked to a collision and the emplacement' could be just written as 'linked to collision and emplacement'  
 1361 3 a comma needed after 'Borneo'  
 1363 27 'subsidence on' should be 'subsidence of'?  
 1364 15 'based on collisional unconformity' should either be 'based on collisional unconformities' or 'based on a collisional unconformity'. In any case, what exactly is a collisional unconformity? Maybe this needs a short explanation or a re-wording.  
 1364 17 'represents the south-dipping' would be better written as 'results from south-dipping'?  
 1367 16 'resulting with' should be 'resulting in'  
 1368 16 delete the word 'block' or change it to 'blocks'?  
 1368 27 change 'which the southwest Borneo' to 'which southwest Borneo'  
 1372 5 It might be clearer to say 'unsubducted' rather than 'remnant preserved'  
 1377 16 '85 Ma as' should maybe be '85 Ma by'

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Interactive comment on Solid Earth Discuss., 5, 1335, 2013.

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