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Interactive comment on "Pacific Plate slab pull and intraplate deformation in the early Cenozoic" *by* N. P. Butterworth et al.

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We thank the reviewers and the editor for taking time to critically evaluate our submission. The manuscript has been greatly improved on the advice of the reviewers. Our responses to specific comments are below, with the reviewer comments italicised for context. The updated manuscript is attached as a supplement to the Reviewer 1 response for referral.

The hypothesis that a change in plate motion ∼50Ma was due to the subduction of the Pacific-Izanagi ridge has up until this point been untested. The exact configuration of the plate boundary including its strike are quite speculative. It's existence and details of its orientation are described in this manuscript as fact, I would recommend a change of language to better communicate to readers the uncertain nature of this ridge. The *change in plate motion is observed to be between 52 and 62Ma which indicates some event occurred with that 10Myr interval, but does not constrain the number of events that caused such change, nor their duration. A more compelling, and quantitative, presentation of this change in plate motion and deformation would be a map showing the difference between the two times (i.e. subtract fig 2 from fig 3 and show change in velocities and deformation).*

This has been discussed in more detail in the text, "The Izanagi plate is now fully subducted and its subducting slab is mechanically attached to the north-west portion of the Pacific Plate. The timing and location of Izanagi ridge subduction is not absolutely resolved (Whittaker et al., 2007; Seton et al., 2012). In our model the Izanagi ridge subducts parallel to the trench. We take into account the highly thinned lithosphere around this area, but we consider it to be mechanically attached to the top of the slab. Thus, in the model, the western flank of the Izanagi ridge is still aiding the pull-force acting on the Pacific plate at 52 Ma. Previous modelling (Burkett and Billen, 2009) suggests ridge subduction is not a pre-requisite for a loss of slab-pull. " Furthermore, we discuss the Euler poles describing the stage rotations of the models. We also show motion paths on Figure 7. And, we put our results in context with Faccenna et al's. (2012) results on slab-pull driving Pacific motions. In doing this we have made clear the plate motion changes as captured by the model, this is also discussed in the 'Model results' section of the paper.

Additionally, the evidence provided is presented by colored maps of the non-dimensional von Mises Criterion. However, presuming that the color bar is linear, this result may appear to be more informative if presented with a log scale, sometimes stress variations appear more readily in log scale.

A log-scale has been used in the updated manuscript, and this highlights the regions of high von Mises much more clearly, thank you.

The information provided on the time-progression and absolute ages of seamounts /

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island chains is not presented in a way that can be directly compared with evolution of stress in the modeled plate, and therefore it is difficult to judge whether or not they coincide.

A new figure has been added to the supplementary section showing the time and spatial progression of the von Mises criterion.

Statement on line 15, page 149 is not correctly referenced as I did not find that statement anywhere in the citation provided

Billen (2008) (paragraph 2, page 332) finds the driving forces are larger than resistive forces for a slab length up to 1000km for a particular test case, however this test case is for a slab of much lower viscosity, so we reason that this depth is an upper limit to contribute to slab pull forces. Conrad and Lithgow-Bertelloni (2002,2004) reason that only upper-mantle slabs aide slab pull, and we assume 10Myr is a coarse, global, approximation for the amount of time a slab will take to reach the lower mantle, and thus this represents the amount of material driving the model. This additional reference is added and is discussed in more detail for clarity, thank you.

Statement on line 14, page 150, I disagree with the statement that the absence of radial viscosity stratification wouldn't affect the plate motions and intraplate deformation. In fact, Morra has published on the fact that it does (Morra et al., PEPI, 2010). It strongly influences the morphology of the slabs at depth, sometimes resulting in folded piles or horizontal accumulations of slabs in the mantle transition zone, which subsequently alter the sinking dynamics due to the varying length scales and shapes of these objects. Secondly, a radial viscosity stratification in the mantle will strongly effect the pressure gradients and slab suction forces that the authors appeal to as an important force for global tectonics including plate motions and plate deformations.

Yes, thank you. Slab morphology at depth will be influenced by viscosity stratification as shown in Morra et al. (2010). And, slab suction forces have been shown to decrease in importance with an increasing lower/upper mantle viscosity contrast. This is discussed

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now in the ‘Model Setup’ section of the manuscript, “A mantle with no viscosity layering simplifies our model, however the role of mantle layering would influence the trench and slab morphology as well as the plateness of a large plate like the Pacific (Morra et al., 2012). Viscosity layering of the mantle would decrease the importance of slab suction relative to slab pull but is probably not sufficient to significantly affect plate motions (Conrad and Lithgow-Bertelloni, 2004).”

The description of the rheology of the plates and slabs provides an insufficient level of documentation for others to attempt reproducing these models.

Additional comments and key references to the BEM-Earth methodology have been provided for a more thorough and complete description of the models. Additional text in the ‘Model setup’ section reads, “Rheology of the plate is defined by an isosurface bounding a region of homogenous density and viscosity (as described in Table 1). We approximate the fluid dynamics of subduction by considering the mantle and the lithosphere as regions of homogeneous density and viscosity, disregarding other chemical and rheological inhomogeneities. We assume a simple temperature independent rheology for such multiphase flow, and model only the fundamental forces controlling the process (Quevedo et al., 2012a), which we take to be: the buoyancy resulting from the different densities between the flow phases; the viscous drag that might hamper or assist plate motion; and the viscous resistance to bending and stretching. The simplified rheology structure is free to deform, and is a simple, yet fair representation for modelling plate-scale lithospheric processes (Capitanio et al., 2010; Li and Ribe, 2012). Each subducting plate is embedded in a homogenous mantle fluid surrounded by an adaptive external surface.”

References

Billen, M.: Modeling the dynamics of subducting slabs, Annu. Rev. Earth Pl. Sc., 36, 325–56, doi:10.1146/annurev.earth.36.031207.124129, 2008.

Conrad, C. and Lithgow-Bertelloni, C.: How mantle slabs drive plate tectonics, Science,

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298, 207 doi:10.1126/science.1074161, 2002.

Conrad, C. and Lithgow-Bertelloni, C.: The temporal evolution of plate driving forces: importance of “slab suction” versus “slab pull” during the Cenozoic, J. Geophys. Res., 109, B10407, doi:10.1029/2004JB002991, 2004.

Please also note the supplement to this comment:
http://www.solid-earth-discuss.net/6/C460/2014/sed-6-C460-2014-supplement.pdf

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Interactive comment on Solid Earth Discuss., 6, 145, 2014.

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