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

Anonymous Referee #1

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Congratulations to the authors for producing a well-written, and well-referenced, and interesting manuscript that investigates the dynamics of global plate motions during plate reconfigurations. I strongly recommend its publication. It is an excellent contribution to the field, of the highest quality that bears upon multiple outstanding questions including plate motion changes, the Hawaiian-emperor Bend, and the development of non-plume related volcanism such as various chains of islands and seamounts. It also indirectly informs us of things like hot-spot reference frames and mechanical properties of the lithosphere. The BEM-Earth tool is uniquely capable type of model that is based on the physics of free subduction models but is also able to take advantage of spherical geometry. This has several advantages which allow for the results of this paper, specifically dynamic models of predicted plate motions based on slab pull (top-down driven) rather than basal tractions of mantle convection (bottom-up). A single plate can

be attached to multiple slabs, as is the case for the Pacific plate during the Cenozoic as well as for today, with northern slabs pulling it in one direction and slabs subducting towards the west pulling it in another.

The work is extending previous results obtained by the group, which has already successfully documented the methodology of BEM-Earth, to now explore how transitions of plate boundaries arising from ridge subduction can influence global plate motions and intraplate deformation/volcanism. This is a new and impressive advance for the geodynamic modeling community that also exhibits the great potential for predictive models, geological hypothsis testing, and highlight the use of observations in constraining models that have considerable uncertainties. The results of this paper demonstrate that absolute plate motions of subducting plates can be reasonably explained with a model of upper mantle slabs as primary driving forces. This is important because it calls into question the validity of models that rely on large scale convective flow to drive plate motions. This paper is able to show that a change in plate motion occurs in dynamic models driven by slab pull of upper mantle slabs in which the purported subduction of a ridge and associated change in amount of subducting slabs attached to the Pacific plate is consistent with the change in plate motion observed in certain plate reconstructions. It is important to note that this conclusion is not based on a circular argument since the predicted plate motions of the dynamic model are independent of the observations used to construct the plate reconstruction. Further, these results demonstrate that the reference frames based on Pacific hotspots likely contain large artefacts that are not related to absolute plate motion.

I have 3 recommendations regarding the presentation that can hopefully improve the manuscript: 1) The hypothesis that a change in plate motion $\sim$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). 2) 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. 3) The information provided on the time-progression and absolute ages of seamounts / 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.

minor comments: 1) statement on line 15, page 149 is not correctly referenced as I did not find that statement anywhere in the citation provided 2) statement 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 lengthscales 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 3) The description of the rheology of the plates and slabs provides an insufficient level of documentation for others to attempt reproducing these models

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