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Solid Earth
Discussions

Interactive comment on "3-D thermo-mechanical laboratory modelling of plate-tectonics" *by* D. Boutelier and O. Oncken

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The referee, Dr. F. Funiciello, noted 5 points that should be addressed to improve the paper. Below we respond to these points.

Point 1: The title of the paper "3-D thermo-mechanical laboratory modelling of plate-tectonics" contains the important information about our study which is that we present the first 3D and thermo-mechanical laboratory experiments of a plate-tectonic process. We acknowledge that it does not convey the idea that the paper mainly deals with the modelling technique rather than modelling results. We now propose a new less catchy but more informative title: "3-D thermo-mechanical laboratory modelling of plate-tectonics: modelling scheme, technique and first

experiments"

Point 2: The relative temperature in the model is approximately scaled. We make two approximations that are very common and very likely do not significantly alter the modelling results. First the temperature gradient in the lithosphere is assumed to be linear while in nature there is heat production in the continental crust. However, the linear approximation is often considered a good approximation. Secondly, temperature in the sub-lithospheric mantle is very homogeneous because of vigorous convection. Our viscosity is so low that the temperature gradient through the whole sub-lithospheric mantle is negligible. With higher viscosity this may not be the case anymore. However, because convection is very vigorous in nature, the assumption of a very low temperature gradient or even isothermal mantle is appropriate. The absolute temperature does not matter, only the relative temperature distribution, which is simplified but reasonable. We now mention these simplifications in the text.

Point 3: This point had been noticed by the second reviewer as well and we will give here the same answer. The presented modelling stands on previous 2D thermo-mechanical experiments where water was used to model the asthenosphere because we were focusing on the solid-mechanics of the plates in the subduction zone and only modelled a limited area. Now we are expanding this modelling in 3D and we will develop our modelling setup towards more dynamical modeling similar to that performed by both F. Funiciello and W. Schellart but with the temperature effect, the ability to control either convergence rate or force and with an overriding plate. In the development path towards this goal there are several milestones that must be reached. The first one was to expand from 2D to 3D. It is presented in this paper. Next we will have to scale the viscous interaction between the lithosphere and asthenosphere or sub-lithospheric mantle. We now present the scaling constraints on the viscosity of the sub-lithospheric mantle in the discussion section. Once this is done we will be able to impose a constant force boundary condition to either the upper or lower plate. We have modified the text to better acknowledge that the viscous interaction between the lithosphere and asthenosphere is currently ignored and that it will be implemented with a higher-viscosity fluid for the asthenosphere in a later developmental stage.

Point 4: We used a rheotec rheometer with a cone-and-plate geometry to perform the rheological tests. A better rheometer capable of oscillatory tests (TA AR 1000 at University of Toronto) has been very briefly tested but the characterization of all the materials mechanical properties at all temperatures had to be performed with the available rheotec rheometer. We describe the testing procedure as well as the results and believe that the materials rheology is sufficiently detailed. Since oscillatory stress/strain amplitude tests were not available we slowly ramped up the imposed shear stress in a series of creep tests. Creep tests can be performed on any kind of materials and do not require that they are linear visco-elastic. However, if the material is not linear visco-elastic we cannot derive a simple viscosity. That is not a problem since the materials are mostly elasto-plastic. Therefore before yield, the creep tests show an elastic behaviour with strain increasing instantaneously with stress and then remaining constant during the duration of the creep step. Strain oscillation tests performed in Toronto revealed that the material do behave elastically prior to plastic failure ($\delta = 10$). When reaching the yield stress, the creep tests show that shear strain increases and this increases is best fitted with a degree-3 polynomial function indicating quasi-linear strain softening. We can further discuss rheometry and the rheology of the materials with the reviewer, however, we believe that the characterization of the material's rheology is sufficiently developed in the manuscript and readers have all necessary information.

Point 5: We have checked the table and changed some scaling factors which were inverted.

Interactive comment on Solid Earth Discuss., 3, 105, 2011.