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Reply on RC2

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Author comment on "Influence of heterogeneous thermal conductivity on the long-term evolution of the lower-mantle thermochemical structure: implications for primordial reservoirs" by Joshua Martin Guerrero et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-418-AC2, 2022

The authors appreciate the comments made by R2 and we address each below. In addition to the commments made by R1, we have decided to thoroughly revise the manuscript so that it is easier to follow.

1. In alignment with the comments of R1, we will expand the introduction section and make the intentions of our study clearer.

2. We calculate the onset time for instability from the temporal variations in the average height of dense material. It is true that these variations in average height do not discriminate between 'intrinsic' (i.e., thermal buoyancy) or 'extrinsic' (i.e., downwellings) deformation. From examining the average height timeseries and animations of the fluid flow we can see the influence of downwellings. The first downwellings impringe on the initial dense layer but do not result in a rapid uplift of material (sufficient to eject blobs of dense material). Once the initial dense layer has organized into piles, downwellings tend to move dense material laterally over the CMB but not rapidly increasing the pile height. Furthermore, we find that it is easier for downwelling currents to push primordial material that has been made lighter due to their retained heat. We agree that downwellings are important in deforming the dense primordial layer. This mechanism will now be discussed in addition to the thermal effect regarding instability.

3. Right. This statement is a bit of a tautology. The intention for this statement is that for Earth-like models that consider a variable thermal conductivity, it may be ill advised to isolate for just one dependency. On one hand, to simulate a 2-pile configuration, a purely depth- dependent conductivity may be employed, but its top-to-bottom ratio should implicitly emulate the temperature and composition effects. On the other hand, a purely temperature-dependent conductivity will result in the entrainment of a dense primordial layer. By assuming a parametrized conductivity model, it is predictable what the mean

conductivity ratio from top-to-bottom will be (having specifed the temperature contrast and the dependencies of the conductivity
model).

4. We will now discuss the reasons why the phase change from perovskite (pv) to post-perovskite (ppv) is ignored in our numerical
model. The effects of the pv-ppv transition properties on the stability and structure of primordial reservoirs has been
investigated previously by Li et al., (2015). There are many controlling parameters for the pv-ppv transition including the
temperature of the CMB, the viscosity contrast between pv and ppv, and the viscosity contrast between ppv and primordial material
that can affect the stability of piles. For instance, weak ppv (i.e., low viscosity contrast between pv and ppv) and a low Tcmb
(i.e., Tcmb ~ 3350 K) can result in entrainment of primordial reservoirs. Because of the model setup we consider in our study,
the inclusion of a pv-ppv transition will result in the entrainment of a dense primordial reservoir. Thus, the pv-ppv phase
transition will mask the effect of thermal conductivity on the stability of primordial reservoirs that we are examining. This
discussion will be added to the new text in the introduction as requested by R1.

5. All usage of the label "K_D = 9.185" will be replaced with "K_{DH}" to indicate that this depth profile was defined by
parameterizations published in Deschamps and Hsieh, (2019).

6. The magnitude of the reduction in thermal conductivity depends on temperature (which changes with depth). A simple
calculation can be added to show how much the conductivity is reduced at CMB temperatures for different n values. The
reduction in conductivity will also be shown by the inclusion of a new figure which shows the initial conductivity profiles for cases featuring K_{DH} with different temperature- and composition- dependence.

7. In alignment with the comments of R1, all usage of "compositional correction" will be rephrased to "composition- dependence".

8. Q_{CMB} and Q_{SURF} will be clearly defined in Section 3.1.

9. As suggested by R1, we will keep consistent with dimensional values. We currently present 2D distributions of thermal
conductivity in Figures 4 and 5. By plotting the conductivity fields relative to the surface value k_{S}, it would be converted
to the non-dimensional conductivity field. We will include the non-dimensional conductivity (the ratio of local conductivity to
surface conductivity) field to the Supplement.

10. Marzotto et al., (2020) will be removed from the references. Conductivity data points included in Figure 1 are from the
references cited within the caption.

11. Coordinates for 3D geometry (x,y,z) or (r,theta,phi) will be replaced by 2D spherical annulus coordinates (r,phi).

12. The potential temperature definition will also be stated in addition to the adiabatic correction.

13. Xu et al., (2004) will be removed from the references. This reference was included in the methods section discussion on the thermal conductivity model (Section 2.2) and had been moved from the supplement to the main text. The reference to Klemens,(1960) in the supplement will also be removed for the same reason.