Response to Review #1

We thank the reviewer for taking the time to read the manuscript and for providing feedback. We have addressed their comments below. The reviewer's comments are in plain text. Our response is in blue, and the excerpts of revised text in the manuscript relevant to the comment are indented, with line numbers provided. Please note that when we refer to a figure, we use the figure number from the revised manuscript.

Review 1:

Through observations in natural rocks, experiments and previous models it is well known that volume increasing hydration reactions, such as serpentinization, lead to fracture nucleation, i.e., reaction-induced fracturing. In their manuscript McElwee et al. bring this process a step forward by investigating how tectonic stresses in various settings influence fracture propagation. Through numerical models they test different stress configurations and find that large fracture networks branching into the surrounding rock form in tensile regimes. To the contrary, in compressional regimes such networks do not form, or only when the reaction is already well advanced, with sever implications on the hydration stage of mid ocean ridges and bending faults. These results are significant and certainly of interest for the community. I only have a few minor comments.

The manuscript is well written and I really enjoyed reading it. Specifically, I acknowledge the detailed discussion on model limitations. All models were run at 1 MPa confining pressure while it is known from experiments that high confining pressures inhibit fracture nucleation. However, I miss a similar discussion on the effect of temperature. We know that the serpentinization rate is sensitive to temperature and maximum reaction rates are reached at 270 – 300 °C. Within the mantle wedge we expect strong temperature gradients, such that reaction rate varies in space as do elastic parameters.

Reaction rate variation that arises due to temperature variation impacts the reaction-induced strain gradient and thus reaction-induced fracture (*Dargi et al., 2025; Shimizu and Okamoto, 2016*). However, because of the low permeability of mantle rock (*Katayama et al., 2020*), the fluid pressure gradient in the region of our interest (where serpentinization is occuring) is likely much larger than the temperature gradient. Additionally, the temperature gradient can probably be incorporated into the Damkholer number, which has previously been taken to define the sharpness of reaction-induced strain gradients (*Shimizu and Okamoto, 2016*).

In other words, when the reaction is fastest the mechanical behavior may favour visco-elasto-plastic rather than brittle responses to the reaction. At higher temperature, the reaction rate slows down, further supporting non-brittle behavior due to decreased strain rates.

We agree with the reviewer that the pattern of reaction-induced fracture may be sensitive to temperature because temperature impacts the reaction rate and thus strain rate. We have some ongoing work on this topic. For now, we have added the following to the manuscript (**Line 825**):

> Additionally, serpentinization and therefore reaction-induced fracture may occur at temperatures up to ~600C in the mantle wedge corner, with the warmest mantle wedge corners, such as in Cascadia, being between 400 and 600C in their entirety (*Wada and Wang, 2009*). At these temperatures, the serpentinization rate is much lower than its maximum rate at roughly 300C (*Malvoisin et al., 2012*), and, therefore, the strain rate due to the volume increasing reaction is probably low. The plastic yield stress of serpentine depends positively on the temperature and negatively on the strain rate (*Burdette and Hirth, 2022; Horn and Skemer, 2025*), and so at these temperatures, non-dilatant plastic deformation may occur (*Malvoisin et al., 2021; Skarbek et al., 2018*) if the plastic yield stress is lower than the brittle strength. This style of deformation, which would likely accommodate strain but does not generate fluid pathways, is not included in our models. The brittle strength is proportional to the effective confining pressure, and so non-dilatant plastic deformation may not be present when the pore pressure is high.

While certain bonds will break and form new fluid pathways, others will ultimately close, which is the often discussed processes of clogging. How exactly is this treated in the model?

We have added the following to the manuscript (**Line 834**):

> Clogging due to precipitation of reaction products in fluid channels is not considered in the models presented here. The entirety of the volume increase goes into elastic and brittle deformation, and the bulk crack density of the model can only increase as the simulation progresses. However, crack and matrix permeability may locally decrease due to elastic stresses that narrows fluid channels at cracks and bonds, as indicated in Figure 4, which may limit supply of fluids to branching cracks. This scenario may be representative of natural serpentinization, given the low permeability of the lithosphere (*Katayama et al., 2020*), which favors fracturing (*Uno et al., 2022*), and the abundance of reaction-induced fracture textures in natural rocks (*O'Hanley, 1995; MacDonald and Fyfe, 1975*).

Furthermore, the volume change may be slightly dependent on pressure and temperature. Possibly this goes too far for this manuscript, but it might be interesting to test how temperature and pressure will affect the volume change and thus the fracture propagation in various tectonic settings.

We are not sure if the reviewer is referring to the solid or total volume change. The dependence of the solid volume change on pressure and temperature is likely small compared to its dependence on other factors, such as mass transport. However, it has been shown that the solid volume change relative to the Damkholer number does indeed impact the fracture behavior (*Ulven et al., 2014b*). The general impact of the solid volume change is noted on **line 344**. Furthermore, the fluid volume change is also sensitive to temperature and pressure. Its effect can potentially be implicitly tested through the Damkhoer number (*Ulven et al., 2014b*). However, the detailed analyses of the effect of solid and fluid volume changes with temperature and pressure is beyond the scope of the current manuscript.

Line 10 (and throughout the manuscript): to refer to the process, change “reaction-induced fracture” to “reaction-induced fraturing”.

We have implemented this change.

Line 40: It could be helpful for the reader to have a reference to figure 6 here.

We have moved Figure 6 to Figure 1 and added a reference at **Line 46**.

Figure 6: In this figure, the compressional and extensional regimes within the mantle wedge could be labelled/highlighted in order to help the reader.

We are not sure if the reviewer means to label the model cartoons, or the mantle wedge corner itself. There are currently labels for the model cartoons. For the mantle wedge corner itself, the stress state likely varies among different subduction zones, and there may be even local variations along strike or dip. See the discussion on **Lines 532–535 and 548–550**.

Line 110: How are the values of P*min* and P*max* determined?

The relatively low Pmax and Pmin values of 29 and 30 MPa, respectively, are chosen such that pore fluid pressure does not cause hydrofracture in the model, as discussed on **Line 127**, but the exact values are otherwise chosen to be consistent with previous work (*Okamoto and Shimizu, 2015; Shimizu and Okamoto, 2016*). We also add some additional reasoning to the text (**Line 312**):

> Additionally, the difference between P_{max} and P_{min} is much smaller than the pressure decrease caused by 100% reaction of an average radius disk. As a result, the reaction is limited by the continual supply of fluids to pore spaces.

References from response text that is not part of a manuscript addition:

Dargi, M. A., Detournay, E., and Le, J.-L.: Eigenstrain-Induced Stress in Elastic Cylinder, Journal of Applied Mechanics, 93, 011006, https://doi.org/10.1115/1.4070149, 2026.

Katayama, I., Abe, N., Hatakeyama, K., Akamatsu, Y., Okazaki, K., Ulven, O. I., Hong, G., Zhu, W., Cordonnier, B., Michibayashi, K., Godard, M., Kelemen, P., and the Oman Drilling

Project Phase 2 Science Party: Permeability Profiles Across the Crust‐Mantle Sections in the Oman Drilling Project Inferred From Dry and Wet Resistivity Data, JGR Solid Earth, 125, e2019JB018698, https://doi.org/10.1029/2019JB018698, 2020.

Okamoto, A. and Shimizu, H.: Contrasting fracture patterns induced by volume-increasing and -decreasing reactions: Implications for the progress of metamorphic reactions, Earth and Planetary Science Letters, 417, 9–18, https://doi.org/10.1016/j.epsl.2015.02.015, 2015.

Shimizu, H. and Okamoto, A.: The roles of fluid transport and surface reaction in reaction-induced fracturing, with implications for the development of mesh textures in serpentinites, Contributions to Mineralogy and Petrology, 171, 1–18, https://doi.org/10.1007/s00410-016-1288-y, 2016.

Ulven, O. I., Storheim, H., Austrheim, H., and Malthe-Sørenssen, A.: Fracture initiation during volume increasing reactions in rocks and applications for CO2 sequestration, Earth and Planetary Science Letters, 389, 132–142, https://doi.org/10.1016/j.epsl.2013.12.039, 2014.