Reviewer 1

Review of Delamination in Tibet: deriving constraints from the density of eclogite by Ye et al.

General comments

This paper established new equations of state for constituent minerals of eclogite and discuss the density of these minerals and eclogite in the mantle depth with implications for possible role of eclogite density in delamination of lower crusts and lithospheric mantle.

High-pressure and temperature experiments seem to have been done nicely in externally heated diamond cell to 700 K. However the experimental temperatures are low compared to the Debye temperatures of the minerals and its applicability to mantle temperatures needs some attention. The choice of the starting material needs clarification. Some of the wordings are not very clear to me, for example, eclogitization of lithospheric mantle does not make sense to me. Some equations are incorrect and wrongly used. I don't think the title represents what the authors studied here, as they did not discuss the mechanism of delamination in Tibet as a function of the density of eclogite; what they did is construction of EoS of the minerals. Therefore, I'm afraid that the current version is not at the publishable level.

Enclosed, please find our replies to the reviewer's comments in our revised manuscript entitled "Delamination in Tibet: deriving constraints from the density of eclogite".

We want to appreciate the reviewer for the thoughtful and thorough comments that have resulted in a substantially improved in the revised version of our manuscript. Point-by-point responses to the reviewer's comments are shown in detail below. We have also indicated our changes are marked in red in the revised manuscript. We believe that we have addressed all the reviewer's concerns adequately.

In the following, the reviewer's comments are shown in boldface and are followed by our replies in normal text. References cited are provided at the end of the response letter.

Specific comments:
1. Comment："The title does not represent what is done in this paper. The authors established EoS of minerals, calculated the density of eclogite and peridotite, and compared them. The only discussion they made regarding delamination processes is the percentage of eclogitizaiton when the rock density reaches the value for isostatic balance. I do not understand how this puts constraints on the delamination processes."
Reply: Thank you for your comment. The purpose of this paper is to emphasize that eclogite is an important factor in the occurrence of delamination and how does the density of eclogite affect the delamination process. The reviewer's suggestion is constructive. We changed our title to: Thermal equation of state of the main minerals of eclogite: Constraining the density evolution of eclogite during delamination process in Tibet.
2. Comment："Why did they use natural samples as the starting material? As the authors said themselves (L300-302), natural samples may not represent what they were in the mantle due to retrograde metamorphism."

Reply: Thank you for your comment. The initial samples used in this study are natural rock-forming minerals of eclogite. By summarizing the composition of exposed eclogititic minerals (Figure 1), we found that the composition of minerals used in this study was within the range of natural rock-forming mineral compositions of eclogite from Tibet. This part was also explained in the Line 152-158. Hence, the natural samples used as the starting material is reasonable. In the Line 300-302, we would like to emphasize that exposed eclogites are usually undergo retrograde metamorphism, and the mineral content does not accurately represent the composition of eclogite. Therefore, we corrected the composition of pre-retrograde eclogites by the content of other minerals.
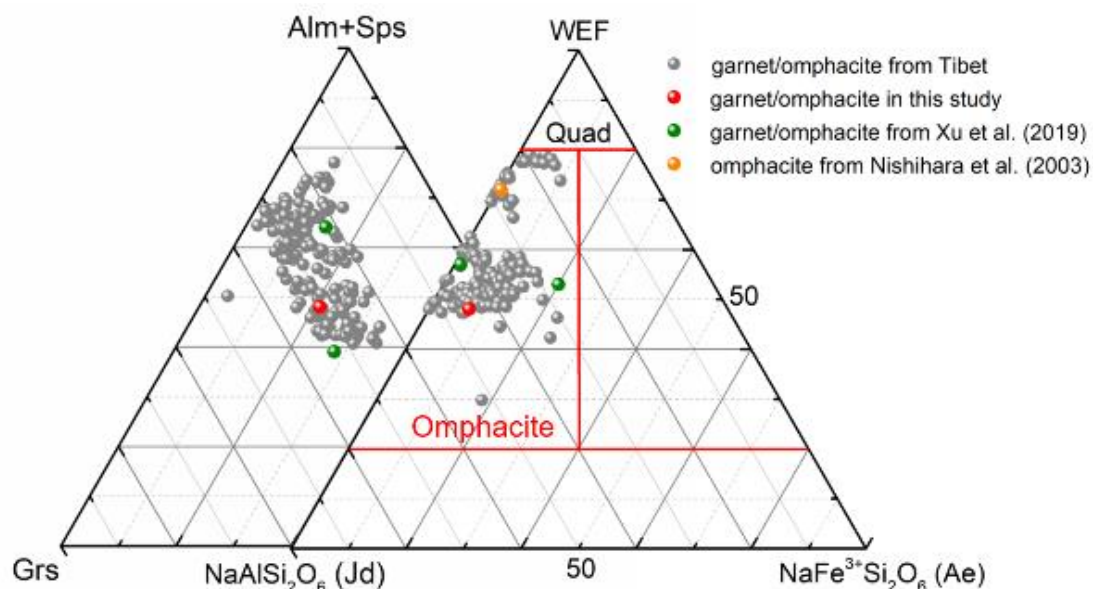
Figure 1. Composition of garnet and omphacite in eclogites from Tibet and this study.
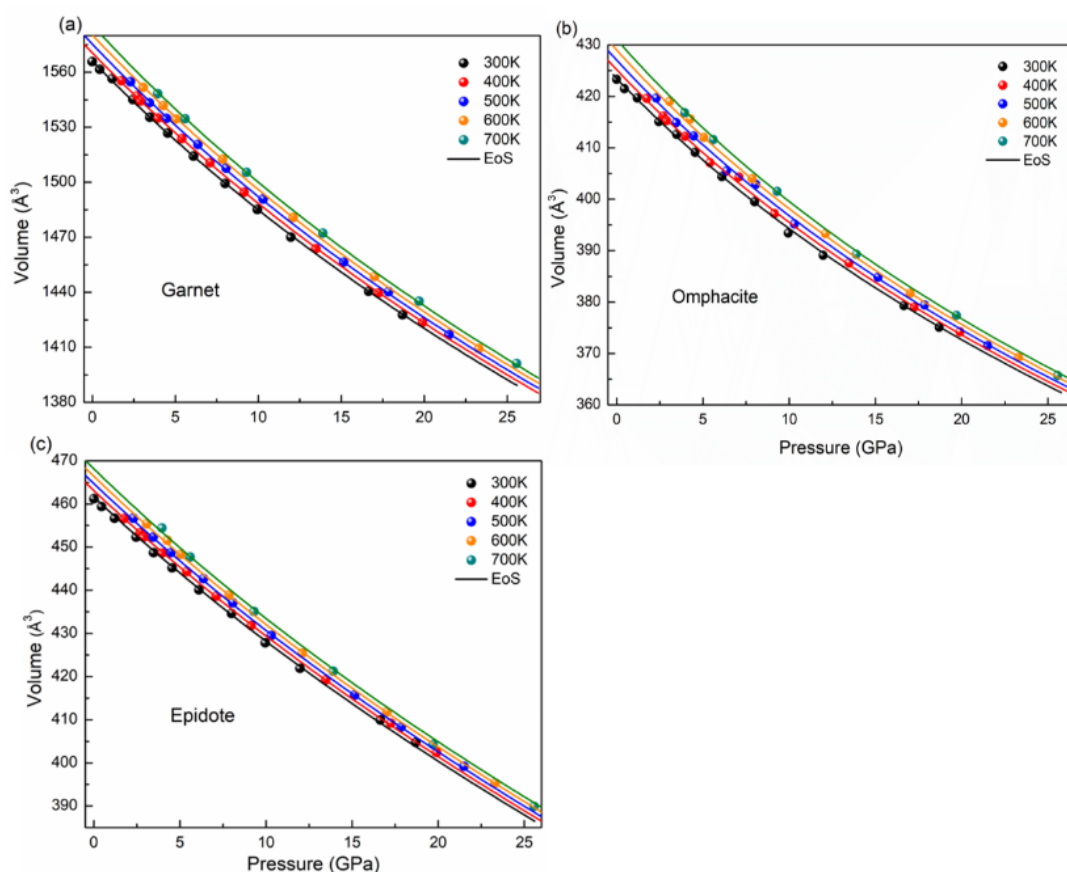
3. Comment :"The thermal EoS was formulated using the high-T Birch-Murnaghan formulation. This is an empirical formulation to describe the high-T behaviour and an extrapolation to the mantle temperature needs attention. Why did not the authors use a thermal pressure model such as using the Mie-Gruneisen relation? The authors should check the high-T behaviour of their EoS by calculating the thermal expansivity at high pressure; it should be increasing with temperature (which will be levelling off above the Debye T). To my eye, omphacite and epidote EoS seem to violate this rule at about 20 GPa, namely the thermal expansivity decreases with T."

Reply: Thank you for your constructive comments. We tried to use the Mie-Gruneisen-Debye thermal-pressure EoS to fit our high-temperature and high-pressure data. Due to the need for some additional parameters and many assumptions required by this model, we can not obtain more appropriate values than using high-T Birch-Murnaghan formulation. Accordingly, we chose another thermal-pressure model Holland-Powell EoS to re-fit our data. The fitting result is shown in Figure 2. The high-T behaviors of omphacite and epidote using this thermal-pressure EoS show more accurate results. The thermal EoS parameters derived from BM3-HP (third-order Birch-Murnaghan compressional EoS in combination with the Holland-Powell thermal-pressure EoS) compared with BM3-Isothermal (third-order Birch-Murnaghan compressional EoS in combination with the Fei-type model) is shown in Table 1, especially the big difference in thermal expansion. From the thermoelastic parameters and the fitted curve, it is apparent that the BM3-HP equation is more suitable for fitting the high-pressure and high-temperature data in this study. We recalculated the

density of the minerals and eclogite through the newly obtained thermoelastic parameters, and made changes in the corresponding figures and texts marked in red.

Table 1. Thermal EoS parameters derived from the fitting of P-V-T data to the BM3-Isothermal EoS and BM3-Holland-Powell thermal pressure EoS.

		BM3-Isothermal	BM3-HP
Garnet	V_0 (Å^3)	1565.8(4)	1566.05(25)
	K_{T0} (GPa)	171.4(8)	170.0(1.3)
	$K_{T'0}$	3.5(1)	3.82(14)
	α_0 (10^{-5} K^{-1})	2.86(9)	2.71(5)
Omphacite	V_0 (Å^3)	423.3(4)	423.48(24)
	K_{T0} (GPa)	122(2)	121.4(2.9)
	$K_{T'0}$	4.1(3)	3.97(34)
	α_0 (10^{-5} K^{-1})	4.1(3)	3.73(20)
Epidote	V_0 (Å^3)	461.2(2)	461.57(23)
	K_{T0} (GPa)	122.7(6)	123.8(1.8)
	$K_{T'0}$	2.49(8)	2.04(15)
	α_0 (10^{-5} K^{-1})	4.7(1)	3.04(13)

Figure 2. Pressure-volume-temperature relations of garnet (a), omphacite (b), and epidote (c). Isothermal compression curves are calculated by using the thermoelastic parameters obtained in this study.

4. Comment："Density is an intensive property and the simple average scheme cannot be applied to obtain the rock density."

Reply: Thank you for your comment. Density in this study is obtained by volume percentage rather than mole percentage. Volume is an extensive property, so the calculated mass is also an extensive property. Furthermore, we assume an ideal condition without taking into account any elastic-plastic interactions between different minerals and any possible deviations from hydrostatic conditions. Most changes of conditions in the Earth proceed slowly, so there is ample time for crystallization to relieve the points of greatest stress and close the pores. Although all rocks have some porosity, they can be largely eliminated by about 1000 atmospheres of pressure, indicates that such readjustments and compensations can be ignored (Robertson, 1988; Skinner, 1966). Moreover, this density calculation profile was also used in previous studies (Faccincani et al., 2021; Ganguly et al., 2009; Ohtani and Maeda, 2001). In the light of these facts, it is believed that the density of any rock under the deep Earth conditions can be obtained by averaging the weighted density of its constituent minerals.

5. Comment："Equations 1 and 4 are wrong. Not sure if these are typos, or the authors calculated those properties using these equations. If they did, all the calculations were incorrectly done."

Reply: Thank you for your comment. We feel sorry for some typos due to our negligence. The correct equations are shown as below:

Equation 1: $\rho(T',0) = \rho_0 \exp\left[-\int_{T_0}^{T'} \alpha(T)\,\mathrm{dT}\right]$

Equation 4: $\rho(T,P) = \rho(T,0)\dfrac{V(T,0)}{V(T,P)}$

For a more detailed description, we modified the equation 4 into the following form:

$$\rho(T,P) = \frac{V(T,0)}{V(T,P)} \times \frac{Z \times M}{N_a \times V_0}$$

6. Equation 2 is not needed here as the authors dropped off the higher terms."

Reply: We agree with the reviewer's comment. Equation 2 here is just to illustrate the expression used for thermal expansion and we did define the thermal expansion of minerals as a constant. We deleted the Equation 2 here.

7. I do not understand what it means by eclogitization of lithospheric mantle. Does this mean mantle peridotite is getting eclogite?"

Reply: Thank you for your comment. The eclogitization here refers to the amount of eclogite in the lithospheric mantle. Previous studies indicate that eclogites in peridotite can originate either by direct HP crystallization of omphacite and garnet from transient melts in the mantle, or by prograde HP recrystallization of plagioclase–bearing basic dikes in peridotite (Medaris et al., 2018). To be more precise, we revised our expressions in the revised manuscript at Line 421-424: "We consider eclogitization in the lithospheric mantle of the subducted slab, here the degree of eclogitization refers to the amount of eclogite in the lithospheric mantle. In our preferred model, the 7-km thick subducted oceanic crust becomes eclogite, while the lithospheric mantle constrains a different amount of eclogite."

References:

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Ganguly, J., Freed, A. M. and Saxena, S. K.: Density profiles of oceanic slabs and surrounding mantle: Integrated thermodynamic and thermal modeling, and implications for the fate of slabs at the 660km discontinuity, Phys. Earth Planet. Inter., 172(3–4), 257–267, doi:10.1016/j.pepi.2008.10.005, 2009.

Medaris, L. G., Brueckner, H. K., Cai, Y., Griffin, W. L. and Janák, M.: Eclogites in peridotite massifs in the Western Gneiss Region, Scandinavian Caledonides: Petrogenesis and comparison with those in the Variscan Moldanubian Zone, Lithos, 322, 325–346, doi:10.1016/j.lithos.2018.10.013, 2018.

Ohtani, E. and Maeda, M.: Density of basaltic melt at high pressure and stability of the melt at the base of the lower mantle, Earth Planet. Sci. Lett., 193(1–2), 69–75, doi:10.1016/S0012-821X(01)00505-2, 2001.

Robertson, E. C.: Thermal properties of rocks., 1988.

Skinner, B. J.: Section 6: Thermal expansion, in Handbook of Physical Constants, pp. 75–96, Geological Society of America., 1966.