General comments

The Tibetan Plateau is one of the most prominent collisional orogens around the world. Understanding the evolution and dynamics of Tibet provides crucial insights into the crust-mantle interactions and subducted processes. In the present study, the authors have conducted simultaneously high pressure-temperature experiments to constrain the density profiles of major minerals of eclogite (garnet, omphacite and epidote), and quantitatively unraveled the effect of density contrast on delamination of Tibet. They concluded that eclogite with a high garnet content and a high iron content and a high proportion of eclogite in the lithospheric mantle promote delamination. The experimental data are of high quality and convincing. Here I highly recommend it for Solid Earth.

Enclosed, please find our replies to the reviewer's comments in our revised manuscript entitled "Thermal equation of state of the main minerals of eclogite: Constraining the density evolution of eclogite during delamination process in Tibet".

We want to appreciate the reviewer for the thoughtful and thorough comments that have resulted in a substantial improvement 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 blue 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: ***Please specify the error in measuring temperature by using thermocouples in Section 3. Please add this information in supplementary tables as well. I wonder if the error in temperature is taken into account when fitting P-V- data to derive thermoelastic parameters.***

Thank you for your comment. For the electrical-resistance heating system, one of the major advantages is the stable and uniform T-distribution within the pressure chamber and the reliable control of temperatures by means of thermocouples (e.g., (Jenei et al., 2013; Miletich et al., 2009; Pasternak et al., 2008)). Moreover, the exceptional thermal conductivity of diamond as the anvil material has the major advantage of transferring heat to the sample inside the pressure chamber. Thus, the key points to obtain the stable and uniform T-distribution within the pressure chamber depend on the stabilization time at high temperature and the tightness of thermocouple glued to the diamond. Back to our high P-T experiments in this study, firstly, ensuring the thermocouple can correctly reflect temperature of sample chamber, we tightly glued the K-type thermocouples with the diamond. To minimize pressure instability and enhance temperature stability for each given heating run, the sample chamber was heated to a given temperature and then stabilize at least 5 minutes. Thus, we believe that the temperature error is very limited within our high P-T measurements in this study because the maximum temperature is just 700 K. This also can be confirmed by (Sinogeikin et al., 2006), who measured the temperature of sample chamber using two thermocouples attached to opposite sides of the diamond in a resistively heated DAC, which is similar with this study, and found the difference in temperature reading from these two thermocouples was within 1 K. To sum up, we did not consider the influence of the temperature error during the fitting process. We added the sentence at Line 170 in the revised manuscript:

"Before collecting data, the temperature in the sample chamber will be stabilized for 5 minutes and the temperature fluctuation is less than 1 K."

2. Comment: ***In Section 4.1, the authors have first fitted the room-temperature data to obtain K0 and K0' at room temperature, and then used both room-temperature and high-temperature data to simultaneously derive K0, K0' and K0. Why did the authors not fix the room-temperature K0 and K0' values to get the thermal expansion parameter? What is the difference between two fitting methods?***

Thank you for your comment. The following Table 1 shows the thermal EoS parameters of eclogite rock-forming minerals obtained by fixing different parameters. The thermal expansions obtained by fixing different parameters are comparable within their uncertainties. This shows that the high temperature and high pressure experimental data obtained in this study are of high quality. Certainly, in our manuscript, the corresponding K_{T0} and $K_{T}'_{0}$ are obtained by fixing V_0, which are obtained from the synchrotron single-crystal X-ray diffraction measurement at ambient conditions. Since the values from high-temperature and high-pressure data are similar to the results obtained by fitting the room-temperature and high-pressure data, we do not fix the room-temperature K_{T0} and $K_{T}'_{0}$ values to get the thermal expansion parameter.

Table 1. Thermal EoS parameters derived from the fitting of *P-V-T* data to the BM3-HP=Third-order Birch-Murnaghan compressional EoS in combination with the Holland Powell thermal-pressure EoS.

Composition	V_0 (Å^3)	K_{T0} (GPa)	$K_{T}'_{0}$	α_0 (10^{-5} K^{-1})	θ_E	
Garnet ($Prp_{21}Alm_{47}Grs_{31}Sps_1$)	1566.05(25)	170(1)	3.74(22)			
	1566.05(25)	170(1)	3.82(14)	2.71(5)	450[a]	Fixed V_0
	1566.05(25)	170(1)	3.74(22)	2.74(3)	450[a]	Fixed V_0, K_{T0}, and $K_{T}'_{0}$
Omphacite ($Quad_{48}Jd_{45}Ae_7$)	423.48(24)	121(2)	3.90(35)			
	423.48(24)	121(3)	3.97(34)	3.73(20)	343[a]	Fixed V_0
	423.48(24)	121(2)	3.90(35)	4.12(11)	343[a]	Fixed V_0, K_{T0}, and $K_{T}'_{0}$
Epidote ($Ca_{2.02}Fe_{0.75}Al_{2.32}Si_{0.16}[SiO_4][Si_2O_7]O(OH)$)	461.57(23)	122(1)	2.51(16)			
	461.57(23)	124(2)	2.04(15)	3.04(13)	626[b]	Fixed V_0
	461.57(23)	122(1)	2.51(16)	2.67(11)	626[b]	Fixed V_0, K_{T0}, and $K_{T}'_{0}$

3. Comment: ***In Section 4.2, the authors have discussed the compositional effect on the elasticity of major minerals of eclogite. One of the main conclusions is that the incorporation of iron would reduce the bulk modulus of omphacite. Do the ferrous iron and the ferric iron impose a comparable effect on the bulk modulus of omphacite?***

Thanks for the constructive advice. We collected the isothermal bulk modulus and its pressure derivative of clinopyroxenes as shown in Table 2. The bulk modulus of Fe-free jadeite is between 125-137 GPa, which is larger than 115-123.6 GPa of other clinopyroxene containing Fe. The addition of iron does reduce the bulk modulus. We collected the bulk modulus of omphacite containing ferrous iron and ferric iron as shown in the figure 1 below. There is no obvious relationship between the bulk modulus of omphacite and the content of ferric iron. The bulk modulus

of Fe-bearing clinopyroxene is between 115-123.6 GPa, but the ferric iron does not show a comparable effect on the bulk modulus. At least from the data we have collected, the effect of ferric iron is limited, and no significant effect on bulk moduli of omphacite can be seen.

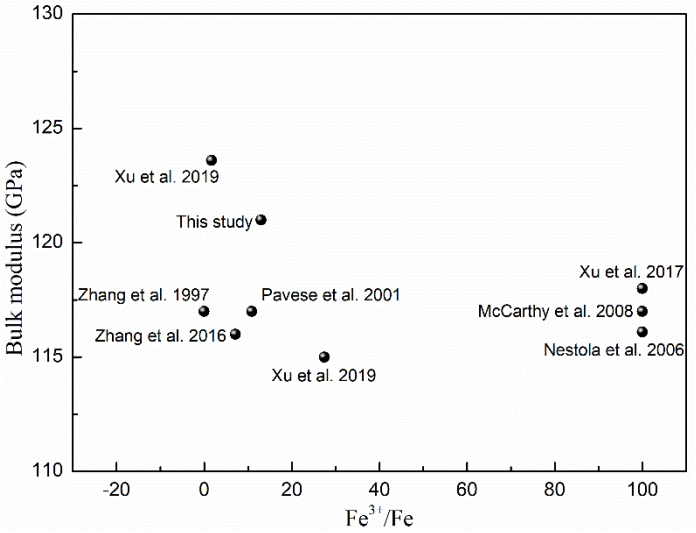

Figure 1. Isothermal bulk modulus and Fe^{3+} content of omphacites and other clinopyroxenes including hedenbergite and aegirine.

Table 2. Isothermal bulk modulus and its pressure derivative of omphacites and other clinopyroxenes including hedenbergite and aegirine.

Composition	Fe^{3+}%	V_0 (Å^3)	K_{T0} (GPa)	$K_T'_0$	References
Jd_{100}	Fe-free	403.32(8)	125(4)	5^{fixed}	(Zhao et al., 1997)
Jd_{100}	Fe-free	402.26(2)	134.0(7)	4.4(1)	(Nestola et al., 2006)
Jd_{100}	Fe-free	402.03(2)	137(1)	3.4(4)	(McCarthy et al., 2008)
Jd_{100}	Fe-free	402.5(4)	136(3)	3.3(2)	(Posner et al., 2014)
Hd_{100}	0	449.90(7)	117(1)	4.3(4)	(Zhang et al., 1997)
$Quad_{57}Jd_{42}Ae_1$	1.7	422.3(1)	123.6(5)	4_{fixed}	(Xu et al., 2019)
$Quad_{52}Jd_{44}Ae_4$	7.1	423.9(3)	116(2)	4.3(2)	(Zhang et al., 2016)
$Quad_{49}Jd_{45}Ae_6$	10.9	422.2(1)	117(3)	6.0(6)	(Pavese et al., 2001)
$Quad_{48}Jd_{45}Ae_7$	12.7	423.48(24)	121(3)	3.97(34)	This study
$Quad_{53}Jd_{27}Ae_{20}$	27.4	426.0(2)	115(2)	4.9(4)	(Xu et al., 2019)
Ae_{100}	100	431.5(1)	118(3)	4.3(3)	(Xu et al., 2017)
Ae_{100}	100	429.26(2)	116.1(5)	4.4(1)	(Nestola et al., 2006)
Ae_{100}	100	429.40(9)	117(1)	3.2(2)	(McCarthy et al., 2008)

4. Comment: ***In Section 5, the authors have modeled the density of eclogite with varying amounts of garnet to explore the effect of mineral compositions on the density of eclogite. What are the partitioning behaviors of ferrous iron and ferric iron in coexisting garnet, omphacite and epidote? Do they alter as a function of pressure (or depth)? I notice that the iron component has distinct effects on the thermoelasticity of these minerals. Does the distribution of iron affect the delamination?***

Thanks for the constructive advice. The partitioning behaviors of ferrous iron and ferric iron in

eclogite rock forming minerals have not been systematically considered before. According to the pressure and temperature conditions of Paleozoic (210-280 Ma) eclogite (Cheng et al., 2012; Tang et al., 2013, 2020; Yang et al., 2009; Zhu et al., 2015) calculated by geothermometer Grt-Omp, the obtained pressures are usually 2.4-3.6 GPa, and the corresponding depth is about 70-120 km. Through specific EMPA data and corresponding P-T conditions, we plotted the relationship of the ferric iron and ferrous iron in garnet and omphacite with depth in eclogites. Since the composition of epidote is limited, it is difficult to consider Fe in epidote here. The ratio of ferric iron and ferrous iron in garnet and omphacite does not show a significant relationship with depth (pressure). For garnet and omphacite in the same location with similar temperature and pressure conditions, the content of ferric iron or ferrous iron in them is different. Moreover, the partitions of ferric and ferrous irons in garnet and omphacite also do not appear to be significantly related to depth (pressure), at least from the data we collected. As far as the composition of Tibetan eclogite is concerned, the iron content does not change regularly with depth. To solve this problem, more natural eclogite rock-forming minerals may be needed to conduct a more systematic calculation of the temperature and pressure conditions, and specific composition.

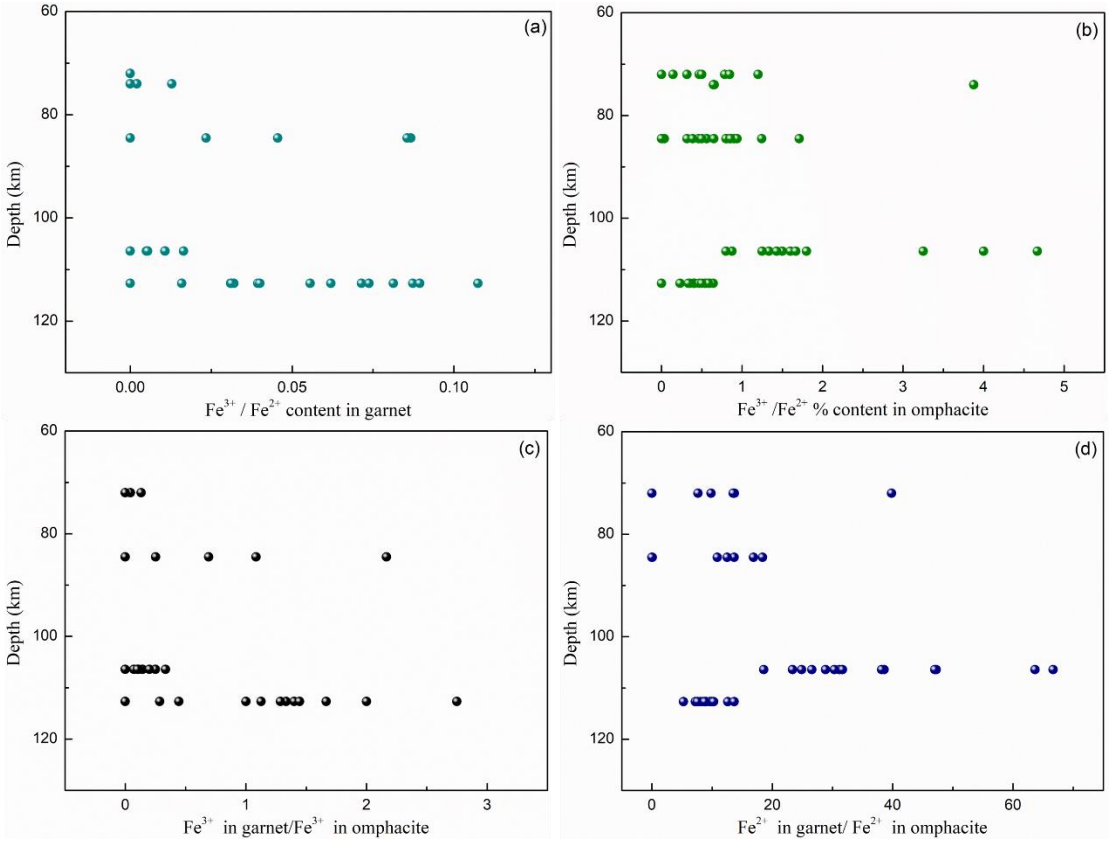

Figure 2. The distribution of ferric iron/ ferrous iron (Fe^{3+}/ Fe^{2+}) in garnet (a) and omphacite (b) with depth. Proportions of ferric (c) and ferrous (d) irons in garnet and omphacite, respectively, as a function of depth.

5. Comment: ***In Section 5, "10% increase in garnet" should be "10 vol% increase in garnet".***

Thank you for your comment. We revised "10% increase in garnet" to "10 vol% increase in garnet" in Line 385 and Line 396.

6. Comment: ***The references of this manuscript is over-cited. The references that are not closely related to the present study could be removed.***

Thank you for your comment. We checked references in our manuscript and removed some less closely related articles.

References:

Cheng, H., Zhang, C., Vervoort, J. D., Lu, H., Wang, C. and Cao, D.: Zircon U–Pb and garnet Lu–Hf geochronology of eclogites from the Lhasa Block, Tibet, Lithos, 155, 341–359, doi:10.1016/j.lithos.2012.09.011, 2012.

Jenei, Z., Cynn, H., Visbeck, K. and Evans, W. J.: High-temperature experiments using a resistively heated high-pressure membrane diamond anvil cell, Rev. Sci. Instrum., 84(9), 095114, doi:10.1063/1.4821622, 2013.

McCarthy, A. C., Downs, R. T., Thompson, R. M. and Redhammer, G. J.: In situ high-pressure single-crystal X-ray study of aegirine, NaFe3+Si2O6, and the role of M1 size in clinopyroxene compressibility, Am. Mineral., 93(11–12), 1829–1837, doi:10.2138/am.2008.2725, 2008.

Miletich, R., Cinato, D. and Johänntgen, S.: An internally heated composite gasket for diamond-anvil cells using the pressure-chamber wall as the heating element, High Press. Res., 29(2), 290–305, doi:10.1080/08957950902747403, 2009.

Nestola, F., Boffa Ballaran, T., Liebske, C., Bruno, M. and Tribaudino, M.: High-pressure behaviour along the jadeite NaAlSi2O6–aegirine NaFeSi2O6 solid solution up to 10 GPa, Phys. Chem. Miner., 33(6), 417–425, doi:10.1007/s00269-006-0089-7, 2006.

Pasternak, S., Aquilanti, G., Pascarelli, S., Poloni, R., Canny, B., Coulet, M.-V. and Zhang, L.: A diamond anvil cell with resistive heating for high pressure and high temperature x-ray diffraction and absorption studies, Rev. Sci. Instrum., 79(8), 085103, doi:10.1063/1.2968199, 2008.

Pavese, A., Diella, V., Pischedda, V., Merli, M., Bocchio, R. and Mezouar, M.: Pressure-volume-temperature equation of state of andradite and grossular, by high-pressure and -temperature powder diffraction, Phys. Chem. Miner., 28(4), 242–248, doi:10.1007/s002690000144, 2001.

Posner, E. S., Dera, P., Downs, R. T., Lazarz, J. D. and Irmen, P.: High-pressure single-crystal X-ray diffraction study of jadeite and kosmochlor, Phys. Chem. Miner., 41(9), 695–707, doi:10.1007/s00269-014-0684-y, 2014.

Sinogeikin, S., Bass, J., Prakapenka, V., Lakshtanov, D., Shen, G., Sanchez-Valle, C. and Rivers, M.: Brillouin spectrometer interfaced with synchrotron radiation for simultaneous x-ray density and acoustic velocity measurements, Rev. Sci. Instrum., 77(10), 103905, doi:10.1063/1.2360884, 2006.

Tang, Y.-J. J., Zhang, H.-F. F., Ying, J.-F. F., Su, B.-X. X., Chu, Z.-Y. Y., Xiao, Y. and Zhao, X.-M. M.: Highly heterogeneous lithospheric mantle beneath the Central Zone of the North China Craton evolved from Archean mantle through diverse melt refertilization, Gondwana Res., 23(1), 130–140, doi:10.1016/j.gr.2012.01.006, 2013.

Tang, Y., Qin, Y., Gong, X., Duan, Y., Chen, G., Yao, H., Liao, J., Liao, S., Wang, D. and Wang, B.: Discovery of eclogites in Jinsha River suture zone, Gonjo County, eastern Tibet and its restriction on Paleo-Tethyan evolution, China Geol., 3(1), 83–103, doi:10.31035/cg2020003, 2020.

Xu, J., Zhang, D., Fan, D., Downs, R. T., Hu, Y. and Dera, P. K.: Isosymmetric pressure-induced bonding increase changes compression behavior of clinopyroxenes across jadeite-aegirine solid solution in subduction zones, J. Geophys. Res. Solid Earth, 122(1), 142–157,

doi:10.1002/2016JB013502, 2017.
Xu, J., Zhang, D., Fan, D., Dera, P. K., Shi, F. and Zhou, W.: Thermoelastic Properties of Eclogitic Garnets and Omphacites: Implications for Deep Subduction of Oceanic Crust and Density Anomalies in the Upper Mantle, Geophys. Res. Lett., 46(1), 179–188, doi:10.1029/2018GL081170, 2019.
Yang, J., Xu, Z., Li, Z., Xu, X., Li, T., Ren, Y., Li, H., Chen, S. and Robinson, P. T.: Discovery of an eclogite belt in the Lhasa block, Tibet: A new border for Paleo-Tethys?, J. Asian Earth Sci., 34(1), 76–89, doi:10.1016/j.jseaes.2008.04.001, 2009.
Zhang, D., Hu, Y. and Dera, P. K.: Compressional behavior of omphacite to 47 GPa, Phys. Chem. Miner., 43(10), 707–715, doi:10.1007/s00269-016-0827-4, 2016.
Zhang, L., Ahsbahs, H., Hafner, S. S. and Kutoglu, A.: Single-crystal compression and crystal structure of clinopyroxene up to 10 GPa, Am. Mineral., 82(3–4), 245–258, doi:10.2138/am-1997-3-402, 1997.
Zhao, Y., Von Dreele, R. B., Shankland, T. J., Weidner, D. J., Zhang, J., Wang, Y. and Gasparik, T.: Thermoelastic equation of state of jadeite NaAlSi 2 O 6 : An energy-dispersive Reitveld Refinement Study of low symmetry and multiple phases diffraction, Geophys. Res. Lett., 24(1), 5–8, doi:10.1029/96GL03769, 1997.
Zhu, D.-C., Wang, Q., Zhao, Z.-D., Chung, S.-L., Cawood, P. A., Niu, Y., Liu, S.-A., Wu, F.-Y. and Mo, X.-X.: Magmatic record of India-Asia collision, Sci. Rep., 5(1), 14289, doi:10.1038/srep14289, 2015.