Reply to Referee Comment #2 (RC2)

Thank you for your feedback, comment, and suggested revision. We appreciate your time and effort in reviewing our manuscript.

We have considered the comments and taken action accordingly. We have made changes to address the majority of the issues raised by the reviewer.

- First, the geochemical model provided is unsufficiently explained. Although the model used refers to another study from Ozawa et al. (2001), some aspects regarding the different parameters used and how their variations could impact the final results would deserve to be more explained and explored. As an example, this is stated in the manuscript that flux of small amounts of carbonatitic melts are involved in forming petit-spot lavas, but the notion of small is relative. Could it be possible to have a more quantitative estimation of such amounts in %, or in terms of carbon content in the lherzolite source even approximative? Besides, could we consider drastic changes in the ultimate model results by varying the critical melt fraction of a certain amount? I suppose the latter could vary depending e.g. on the melt composition ('better' connectivity of a carbonatitic liquid compared to a basalt typically).

- Thank you for your comment. This is mass-balance based model, and then a flux ratio of 0.1 means that there is a 10% flux contribution to the mass of the melting source. In other words, γ = 0.1 means a flux of 0.1 for a melting source of mass 1. Therefore, we have rephrased the “low carbonatite influx” to “<u>10% carbonatite influx to a given mass of source</u>”.

We also conduced the model considering the different garnet mode and melt connectivity (critical melt fraction) in addition to previously conducted models. Please see the new Fig. 11, its caption, and line 708-708, 717-737 and 827-828 in the revised manuscript.

- Regarding the origin of fluxing carbonatitic melts as discussed in l. 775-791 in section 6.4, some sources are discussed: “subducted carbonated pelite, pyroxenite/eclogite, or peridotite stored as diamond or metal carbide in the reduced lower portion of the upper mantle(….or) the existence of a carbonate-rich layer in the LAB owing to the horizontally spread carbonate from around the wedge mantle rather than upwelling from the deep mantle”. Carbonatites can be produced by melting of such lithologies, and I do not contest these possible origins, but since decades now, plethora of publications in experimental and modeling petrology have demonstrated upper parts of the asthenosphere, where the bottom layer of LAB is probably located, can be enough oxidized to have an ‘original’ source of carbon hosted as carbonates, and within the P-T conditions prevailing in this region, such carbonates can melt to form carbonatites (see e.g. Massuyeau et al., 2021). In this convective mantle, deep we get carbonatites and by ascending into the mantle, the melt composition gets close to a basalt with a kind of opposite trend between the enrichment in silica and the carbon depletion. Besides carbonatites can also be stabilized in the deepest and cold parts of the lithosphere. So, this scenario appears as most likely to explain formation of carbonatites in the LAB region than those explained above as source for carbonatites, and should at least deserve to be discussed too.

- Thank you for your comments and instructions. We checked Massuyeau et al. (2021) along with Massuyeau et al. (2015).

  The introduced papers are very interesting, and we added the discussion based on them in the introduction part and discussion part. We newly described another origin of carbonatite and depth-dependent chemical variation; carbonatite, kimberlite, and alkali basalt. Please see the line 89-94, 787-793 in the revised manuscript.

- 44-46 : The two first sentences of the abstract should be reworked. As it, it can let imagine the manuscript will discuss about the origin of the geophysical discontinuities observed at LAB, while this is not the purpose of the manuscript. And the first sentence could be removed to my mind.

- Thank you for your comments. Another reviewer also pointed out this part as:

Reviewer#1 " the data in the manuscript do not contribute to define the origin nor the structure of the LAB. The model provided is only petrogenetic. The opening of the abstract must be modified."

We revised here as:

"Petit-spot volcanism, which occurs owing to the plate flexure, were reported around the world. The petit-spot melts ascent from the asthenosphere, and provide the essential information of the upper mantle."

Please see the line 43 to 45 in the revised manuscript.

- 57-58 : "… *partial melting of garnet lherzolite with a small degree of carbonatite melt flux with 58 crustal components.*" à I understand the crustal component are brought by carbonatitic melts, which is probably not the case here, right?

- Yes. In our model, carbonatite is the influx and crustal component is mixed in the source. However, both contribute to sources of melting.

- 59-60 : "…*and provides an implication for the genesis of tectonic-induced volcanism with similar geochemical signatures to those of petit-spots.*" à I do not understand this sentence.

- This meant that tectonically induced volcanoes with trace element compositions similar to our sample, such as NorthArch and other petit-spit like rejuvenated volcanoes (such as Tonga Trench), could also be explained by a similar model.

We revised the phrase as:

"… and provides an implication for the genesis of tectonic-induced volcanoes including Hawaiian North Arch volcanics and Samoan petit-spot-like rejuvenated volcanoes having similar trace element composition to petit-spot basalts."

Please see the line 57 to 58 in the revised manuscript.

- 68 : add a reference to the geochemical modeling done in the study

- Thank you for suggestion. We added the phrase about it:

" ….LAB. We conducted geochemistry, geochronology, and geochemical modeling for petit-spot volcanoes on the…."

Please see the line 66 to 67 in the revised manuscript.

- 88-89 : It would be interesting to mention that with variations of P-T, as it can occur at LAB potentially, melting of carbonated peridotite can also produce a chemical continuum in the composition of produced melts, from carbonatite to basalt, with intermediate terms like kimberlites, nephelinite, melilitite, etc. It could possibly partly explain the variations obtained in terms of major elements between different series.

- Thank you for your advice. We revised this part as:

"In addition, carbonatites and Si-undersaturated melts are generated through partial melting of CO2-bearing or carbonated peridotite. The produced melts could exhibit continuous chemical variations depending on pressure (i.e., depth), that is, carbonatitic melts are produced in the deep asthenosphere (300 km to 110 km), while carbonated or alkalic silicate melts are generated in the shallower upper mantle (~110 km to ~75 or 60 km) (Keshav and Gudfinnsson, 2013; Massuyeau et al., 2015, 2021)."

Please see the line 89 to 94 in the revised manuscript.

- 100 : Instead of "*carbonatitic materials*", I would rather use "*carbonated materials*".

- Thank you for your remark. We revised the phrase as you said. Please see the line 104 in the revised manuscript.

- 101-105 : As the notion of LAB and its relationships with both mantle melting and geophysical properties have not been discussed yet (coming next in the Background section), I would replace "LAB" by "the uppermost part of the asthenosphere" or similar, something more neutral in the description.

- Thank you for your instruction. We revised “the LAB” to “the uppermost part of the asthenosphere” as you mentioned. Please see the line 105 in the revised manuscript.

- 119 : As you mention the LAB, it would be appropriate to have a short and general discussion/presentation about the latter and its relationships with mantle melting and geophysical signatures. Besides, once considered the notion of LAB, could we consider the bottom of a possibly metasomatized lithosphere as a possible source of petit-spot lavas too ?

-Thank you for your suggestion. We added the sentence about LAB as:

“The LAB is identified as a discontinuous transition in seismic velocities at the base of the lithosphere, and its causes are attributed to hydration, melting, and mineral anisotropy with considerations for the unique characteristics in each tectonic setting (e.g., Rychert and Shearer, 2009). The occurrence of petit-spot volcanism substantiates the existence of melt at the LAB below the area at least (Hirano et al., 2006)”

Please see the line 125 to 129 in the revised manuscript.

The bottom of metasomatized lithosphere as a source of melts at LAB was discussed as a metasomatized amphibole-rich vein in the lithosphere (Section 6-3, line 681 to 688).

- 143 : The authors mention a low-velocity zone, but no reference is mentioned. Same in line 144-145. Moreover, it would deserve more explanation, why do they need to mention. This is kind of information from nowhere.

- Thank you for your remark. We added some description of vicinity seamounts with references, the reference of seismic data, and that no heat supplies have been reported. Please see the line 156 to 159 in the revised manuscript.

- 451-452 : Here authors should also precise that the samples 1203 and 1206 are from another study (Hirano et al., 2019)

- Thank you for your remark. We added the description and reference in the caption of Fig.4 (1203 and 1206; Hirano et al., 2019 and 1466R7; Mikuni et al., 2022). Please see the caption of Fig. 4 in the revised manuscript.

- 452-454 : Any kind of filtering done from the PetDB database ?

- The plotted data were not filtered, and then we compiled the data again using "Expert data set of Stracke et al. (2022)" for MORB and OIB which can be clearly seen the information of data. Additionally, following the comment of reviewer#1 of "*Plotting the literature data for kimberlites causes a "squeezing" of the OIB data down to K2O/Na2O <1.5, with all the data overlapping with each other. Is this really necessary?*", we changed the Fig. 4b to Na2O vs. K2O plot, and kimberlite plot were discarded. The max K2O/Na2O value from PetDB was only used in the Figure.

Please see the new Fig. 4 and its caption.

- 488 : "*with Bizimis et al. (2003)*" à it could be of interest to precise this point, e.g. as part of the Supplementary part

    - Thank you for your suggestion. The symbols of the carbonatite by Bizimis et al. (2003) were highlighted with a border in Fig. 9, and they show the clear HIMU-EM1 trend.

- 564 : "*were suggested*" à By who ? If this is the authors suggestion, they should use the present tense then, here readers could think they are mentioning another reference not cited.

- Thank you for your instruction. The phrase of "were suggested to" was changed to "are implied to". Please see the line 567 in the revised manuscript.

- 595-596 : Could we simply imagine this LOI being a volatile (CO2-H2O) rest of the primary melt ? Does the Figure 8 completely rejects this hypothesis ? In terms of major elements (Fig. 5), it seems difficult to exclude completely this hypothesis relatively to other samples, except maybe the high FeO content. Does the latter could maybe favor your alteration scenario ?

655-660 : To reconsider in light of the previous comment regarding the nature of 1466R7.

- Certainly, among the two samples characterized as altered rocks, namely 1466R7-001 and R7-003, it might be reasonable to consider R7-001 with an LOI of 2.86 as a more primary sample, as suggested by the Sm/Hf ratio vs. MgO plot. However, it seems unlikely that the LOI is indicative of primary CO2 or H2O. This is because, according to Okumura and Hirano (2013 geology), the post-eruption CO2 content in NW Pacific petit-spot samples, even at its highest, is 1200 ppm, with H2O content at 0.6 wt%. Furthermore, the absence of minerals such as amphibole or mica, unlike in kimberlites, suggests that these volatile components are of secondary origin.
- The absence of fresh glass, the prevalence of hydrated olivine, and some spikes in trace elements like negative anomalies in Sr further led us to refrain from designating it as a representative sample.

- 741-744 : It seems to be in contradiction with what is said in previous sentences, no ?.. Maybe this sentence would need to be reworked a bit.

- We wanted to insist that we cannot connect the mantle endmember (HIMU and EM-1) to carbonatite or recycled crust, respectively, and it is difficult to suppose representative isotopic ratios of them (particularly carbonatite).

We revised here as:

“The variability of global carbonatite isotopic compositions also makes it difficult to determine their representative isotope ratios (Fig. 9). Although such issues make a quantitative isotopic mixing model challenging, the HIMU-EM-1 like trend of the global petit-spot volcanoes may reflect the involvement of carbonatitic and recycled crustal materials.”

Please see the line 766 to 769 in the revised manuscript.

- 767-770 : I do not understand the point here, it seems both sentences repeat the same point with different locations for 'representative' carbonatites.

- Thank you for your remark. As the reviewer #1 suggested to remove most of Section 6-4, we deleted the line 765 to 774 in the firstly submitted manuscript including line 767–770.

- 780-781 : “transition oxidation state” à it would deserve more explanation

  - Thank you for your remark. We added the phrase as (under lined part):

  “Subducted carbonated pelite, for example, would melt under high pressure (>8 GPa) through the oxidation at the redox boundary where the the iron-wüstite (IW) buffer changes to the quartz–fayalite–magnetite (QFM) buffer (i.e., redox melting; Grassi and Schmidt, 2011).”

  Please see the line 778 to 780 in the revised manuscript.

Technical corrections

Thank you for your careful review and taking the time out of your busy schedule. We revised as your corrections. For other cases, some comments are included.

- 52 : remove “*their*”
- 65 : replace “*moving*” with “*motion*” (line 64)
- 65 : replace “*on*” with “*over*” (line 64)
- 92 : “*to be explained*” (line 97)
- 101 : replace “*LAB*” with "*Lithosphere-Asthenosphere Boundary (LAB)*"

\- Following your previous comment, we changed the phase LAB to “the uppermost part of the asthenosphere” (line 105)

- 119-120 : replace “*leading to an understanding*” with “*and further leading to a better understanding*”

\- Following reviewer#1’s comment, we changed the sentence here. (line 121 to 125)

- 144 : replace “*Although the*” with “*In spite of*”

- Following reviewer#1’s comment, we replace here with “Notwithstanding”. (line 156)

- 219 : “*and comprised*” (line 233)
- 329 : replace “*The*” with “*Both*” (line 346)
- 344 : replace “*value was*” with “*values were*” (line 361)
- 377-378 : replace “*In the model in this study*” with “*In this present study, the model uses a critical melt fraction*”, and remove “*was*” in l. 379. (line 694 to 695)
- 544 : replace “was” with “is”, the petit-spot volcanic field still exists I guess ;-) (line 546)
- 566 : “*K#1466R3*” right ?

- That’s right. Thank you. (line 569)

- 570 : replace “*this*” with “*these*” we revised “this study samples” to “these samples”. (line 573)
- 590 : replace “might affect” with “*might have affected*” (line 593)
- 733 : remove one “*the*”
- 787 : “*Hammouda et al. 2021*” ?

  Sorry, Hammouda et al. (2020) is correct, and the caption of Fig. 12 was incorrect. We revised the reference in the caption of Fig. 12.

The revised points other than the reviewer's pointed out.

・We verified that the glass analysis data obtained through EPMA represented an average of 10 points. Subsequently, this information was incorporated into the method section. Additionally, Table 2 includes 2-sigma values, and the notation "n=10" has been included.

・The term "detrital zircon" was amended to "zircon in peperite."

・Certain passages were changed from past tense to present tense.

・Symbols representing NW Pacific petit-spots were standardized.

・The PM-normalized trace element range of NW Pacific petit-spots (Fig. 7g) was adjusted using data from Hirano and Machida (2022).