

Light oxygen isotopic composition in deep mantle reveals oceanic crust subduction before 3.3 billion years ago



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Decision letter and referee reports: first round

5th Oct 23

Dear Dr Ouyang,

Your manuscript titled "Low- $\delta^{18}\text{O}$ deep mantle reservoir reveals oceanic crust subduction before 3.3 billion years ago" has now been seen by 2 reviewers, and we include their comments at the end of this message. Both reviewers gave positive feedback on the manuscript. They find your work of interest, but some minor points are still raised. We are interested in the possibility of publishing your study in *Communications Earth & Environment*, but would like to consider your responses to these concerns and assess a revised manuscript before we make a final decision on publication.

We therefore invite you to revise and resubmit your manuscript, along with a point-by-point response that takes into account the points raised. Please highlight all changes in the manuscript text file.

We are committed to providing a fair and constructive peer-review process. Please don't hesitate to contact us if you wish to discuss the revision in more detail.

Please use the following link to submit your revised manuscript, point-by-point response to the referees' comments (which should be in a separate document to any cover letter), a tracked-changes version of the manuscript (as a PDF file) and the completed checklist:

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Please do not hesitate to contact us if you have any questions or would like to discuss these revisions further. We look forward to seeing the revised manuscript and thank you for the opportunity to review your work.

Best regards,

Renbiao Tao, PhD
Editorial Board Member
Communications Earth & Environment
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Joe Aslin
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REVIEWER COMMENTS:

Reviewer #1 (Remarks to the Author):

Review on COMSENV-23-1201-T

This paper presents a combined study of O isotopes and major-trace elements in olivine grains of the 3.27-Ga komatiites from the Barberton Greenstone Belt in South Africa. The results show a series of differences in these geochemical composition of olivine grains. The olivine grains are categorized into two groups in terms of their O isotope compositions. Whereas one group exhibits normal mantle-like $\delta^{18}\text{O}$ values of 4.9-5.4‰ with higher Fo numbers of 93-95, the other group

Decision letter and referee reports: first round

shows lower $\delta^{18}\text{O}$ values of 3.6-4.7‰ with slightly lower Fo numbers of 91-93. These $\delta^{18}\text{O}$ values are correlated with other geochemical proxies such as NiXFeO/MgO, Ca/Fe, Zn/Fe and Co/Fe for olivine-poor iron-rich pyroxenite sources. Therefore, it is concluded that the target komatiites were derived from two distinct mantle sources. The $\delta^{18}\text{O}$ olivine grains are interpreted to crystallize from low $\delta^{18}\text{O}$ magmas, whose source was modified by subduction-related recycling of the altered oceanic crust into the deep mantle. In this regard, the oceanic subduction would have started 3.3 billion years ago, indicating the onset of plate tectonics at that time. This process is also responsible for the mantle heterogeneity in the Early Archean.

In general, this is a well-organized paper and thus an important contribution to Archean geochemistry. The newly reported O isotope data are novel and their interpretations are sound, providing the geochemical evidence for crustal recycling through the operation of plate tectonics as early as 3.27 Ga in the late Paleoproterozoic. Hence, this paper merits publishing in CEE.

Nevertheless, there are a number of problems in the presentation including literature citation. Whereas the low $\delta^{18}\text{O}$ komatiites provide robust evidence for crustal recycling by subduction in the late Paleoproterozoic, the interaction between the crust and mantle of Earth may be traced back to the Eoarchean when stagnant lid tectonics was transforming to mobile lid tectonics. Therefore, a minor revision is necessary before accepting it for publication.

Specific comments:

1. Line 15: It had better to state "the subduction of oceanic slabs" rather than "the subduction of recycled slabs".
2. Line 20: It had better to put "normal" before "mantle-like $\delta^{18}\text{O}$ values".
3. Line 26: It had better to state "recycling of the altered oceanic crust" rather than "recycling altered oceanic crust".
4. Line 40: Meteoroid impacting is a process of exogenesis rather than a top-down process.
5. Lines 190-191: This statement is problematic. It is the crustal eclogite that is generally deemed as the metamorphic product of deeply subducted oceanic crust.
6. Line 195: Had the Archean seawater $\delta^{18}\text{O}$ values as low as -10 to -5 ‰? Such low $\delta^{18}\text{O}$ values are meteoritic water rather than seawater. The problem may be derived from the uncertainty in three O isotope analyses (Galili et al., 2019; Guo et al., 2022). The traditional two-oxygen isotope analyses gave higher $\delta^{18}\text{O}$ values of -2‰ to 0‰, close to that for modern seawater.
7. Line 198: "This estimation" read "This estimate".
8. Line 202: "widely in enriched OIBs" read "widely to geochemical enrichment of OIBs".
9. Lines 234-236: Although most TTG display normal mantle-like $\delta^{18}\text{O}$ values, there is evidence of low $\delta^{18}\text{O}$ TTGs from the Kaapvaal Craton in South Africa (Wang XL et al., 2022, National Science Review, 9: nwab136). In this regard, the mafic residues could have $\delta^{18}\text{O}$ values lower than the normal mantle values.
10. Line 259: It had better to state "paired high T/P and intermediate T/P metamorphism" rather than "paired high dT/dP and intermediate dT/dP metamorphism", because this statement has been upgraded by Brown and Johnson (2019, American Mineralogist 104, 1065-1082). For the nature of paired metamorphic belts in the Archean, it had better to refer to Zheng and Zhao (2020, Science Bulletin 65, 329-334).
11. Lines 265-266: This sentence is problematic. It had better to state "Combined these lines of evidence demonstrate the onset of plate tectonics in the Paleoproterozoic, which recycled the crustal materials into the mantle."

Reviewer #2 (Remarks to the Author):

Review of the manuscript: "Low- $\delta^{18}\text{O}$ deep mantle reservoir reveals oceanic crust subduction before 3.3 billion years ago" By Ouyang et al.

I have read the manuscript with great interest since it discusses the evolution of the Archean mantle and the start of subduction, the topic I am interested in. The authors used details of Oxygen isotopes and geochemical data of quite fresh olivine grains from Weltevreden komatiites (3.3 Ga) to identify an interesting low $\delta^{18}\text{O}$ olivine group that gives a strong indication about the recycling of terrestrial materials into the deep mantle. After reading this MS, I can say that the authors did a very good job making the MS ready for publication after a few more suggestions.

Decision letter and referee reports: first round

There is just one major comment for the authors to be considered:

- Can you add a more detailed section about the effect of alteration/serpentinization on your olivine? You can explain in detail the petrographical and geochemical observations effects of the secondary process on your olivine, to show that your low- $\delta^{18}\text{O}$ isotopic is the primary signature.

Below are line (L) comments that hopefully are useful to the authors:

L38: Gamaleldien et al. 2020 SR, can be added to the subduction part.

L52: Add reference, please. Valley work?!

L130-133: Can you add a supp figure to show those geochemical relationships?

L195-200- How you did do this estimation and assumptions? Can you develop this model using Monto Carlo modeling?

L231-234: Please add RFF: Gamaleldien et al. 2020 SR

Regards,

Hamed Gamaleldien

02/10/2023, Khalifa University-UAE

Response

We thank the reviewers for their suggestions and comments on the manuscript, which we found very useful in refining and improving our manuscript.

The most significant modifications include the addition of an illustration- Extend Data Fig. 2, a binary diagram of some representative elements with MgO contents for Weltevreden komatiite samples, to show the olivine control of the whole-rock compositions; the addition of major-trace elements data for serpentine, and the addition of a paragraph in Supplementary Materials (Section 4) discussing the potential effects of alteration on olivine.

The following is our revision and discussion of the reviewers' comments line by line.

Reviewer #1

1. Line 15: It had better state “the subduction of oceanic slabs” rather than “the subduction of recycled slabs”.

We have amended the expression. Now in Line 17

2. Line 20: It had better to put “normal” before “mantle-like $\delta^{18}\text{O}$ values”.

We have amended the expression. Now in Line 22

3. Line 26: It had better state “recycling of the altered oceanic crust” rather than “recycling altered oceanic crust”.

We have amended the expression. Now in Line 28-29

4. Line 40: Meteoroid impacting is a process of exogenesis rather than a top-down process.

Here we would like to express the genesis of mantle heterogeneity, one due to crust-mantle interactions and one inherited from earlier source regions. The process of meteorite impact is behaviorally top-down, but this process is indeed exogenous, and it is necessary to distinguish it from the recycling of crustal material. We have amended the expression.

Now in Line 53 as “In addition, meteorite impacting as an exogenetic process is also a potential model.”

5. Lines 190-191: This statement is problematic. It is the crustal eclogite that is generally deemed as the metamorphic product of deeply subducted oceanic crust.

Mantle eclogites are meta-basaltic to picritic rocks that were entrained as xenoliths from subcrustal depths by kimberlites sampling cratonic lithospheres (Jacob, 2004 *Lithos*). In fact, many researchers believe that a model of mantle eclogite origin by the transformation of oceanic crust is very convincing and has now reached the status of a dominant paradigm (Aulbach and Jacob, 2016 *Lithos*; Korolev et al., 2018 *ESR*). The crustal eclogite refers to the eclogites in continental orogenic belts and represents the deep subduction of the continental lithosphere (Zhang and Zhang 2022 *Earth Science Frontiers*).

6. Line 195: Had the Archaen seawater $\delta^{18}\text{O}$ values as low as -10 to -5 ‰? Such low $\delta^{18}\text{O}$ values are meteoritic water rather than seawater. The problem may be derived from the uncertainty in three O isotope analyses (Galili et al., 2019; Guo et al., 2022). The traditional two-oxygen isotope analyses gave higher $\delta^{18}\text{O}$ values of -2‰ to 0‰, close to that for modern seawater.

The oxygen isotope composition of ancient seawater is a matter of great controversy. Different studies have yielded different results, with some suggesting that the $\delta^{18}\text{O}$ values of ancient seawater were lower than those of modern seawater (Galili et al., 2019 *Science*, based on the $\delta^{18}\text{O}$ record in marine iron oxides; Guo et al., 2022 *EPSL*, based on a comprehensive model of solid Earth evolution coupled to a mass balance model of seawater oxygen isotope ratios), others coming to the opposite conclusion (Johnson and Wing, 2020 *Nat. Geosci*), and still others suggesting that seawater's oxygen isotope values have been stable since the Archean (Peters et al., 2020 *EPSL*). The main factors controlling the variation of oxygen isotope values in seawater are water-rock interactions with rocks at different temperatures and weathering inputs following continental uplift above sea level. Here, based on the oxygen isotope compositions of modern altered oceanic crust (as low as -2 ‰, Gao et al., 2012 *G-cube*) and the previous conclusions, we tend to think that the oxygen isotope values of Archean seawater are low, and the proportion of high-temperature hydrothermal alteration may also be higher in the Archean, which will lead to the high-T altered oceanic crust with lower oxygen isotope compositions. Here, we just wanted to constrain the amount of recycled oceanic crust, so we chose 0-2 ‰ as the oxygen isotope value for high-T altered oceanic crust. In addition, the accuracy of triple-isotope testing can already reach less than 5 ppm, and the composition of triple isotopes is equally important for the qualification of ancient seawater oxygen isotopes in future studies because $\delta^{18}\text{O}$ and $\delta^{17}\text{O}$ are related to each other.

7. Line 198: “This estimation” read “This estimate”.

We have amended the expression.

8. Line 202: “widely in enriched OIBs” read “widely to geochemical enrichment of OIBs”.

We have amended the expression.

9. Lines 234-236: Although most TTG display normal mantle-like $\delta^{18}\text{O}$ values, there is evidence of low $\delta^{18}\text{O}$ TTGs from the Kaapvaal Craton in South Africa (Wang XL et al., 2022, National Science Review, 9: nwab136). In this regard, the mafic residues could have $\delta^{18}\text{O}$ values lower than the normal mantle values.

In fact, most of the zircon $\delta^{18}\text{O}$ values (5-7.1‰) in Wang et al. 2022 NSR are higher than normal mantle values. Again, they emphasize that these high oxygen values reflect the fact that the source has been modified by low-temperature water-rock interactions on the surface, then recycled into the deep crust possibly by plate subduction. Here, we would like to emphasize that in the delamination model, the basal lower crust (or remnants) did not have the opportunity to undergo modification effectively by water-rock interactions, and thus most of their oxygen isotope values are normal mantle values. Despite individual anomalies, most of the TTG show normal mantle $\delta^{18}\text{O}$ values, indicating that most of the melt residues have normal oxygen isotope values. In addition, we emphasize that the model of delamination cannot reach the lower mantle scale (Bédard, 2018 Geoscience Frontiers).

10. Line 259: It had better to state “paired high T/P and intermediate T/P metamorphism” rather than “paired high dT/dP and intermediate dT/dP metamorphism”, because this statement has been upgraded by Brown and Johnson (2019, American Mineralogist 104, 1065–1082). For the nature of paired metamorphic belts in the Archean, it had better to refer to Zheng and Zhao (2020, Science Bulletin 65, 329-334).

We have amended the expression.

11. Lines 265-266: This sentence is problematic. It had better to state “Combined these lines of evidence demonstrate the onset of plate tectonics in the Paleoproterozoic, which recycled the crustal materials into the mantle.”

We have amended the expression.

Reviewer #2 (Remarks to the Author):

There is just one major comment for the authors to be considered:

- Can you add a more detailed section about the effect of alteration/serpentinization on your olivine? You can explain in detail the petrographical and geochemical observations effects of the secondary process on your olivine, to show that your low- $\delta^{18}\text{O}$ isotopic is the primary signature.

First of all, according to the BSE images (Fig. 1), we can clearly observe the structure of olivine. Some olivine is almost unaffected by alteration and shows only very thin alteration rims, and some grains show complex alteration structures. From the mineral composition, we also analyzed different domains of the same grains by EPMA and LA-ICP-MS, the results show significant compositional differences between olivine and serpentine. Serpentine has a wide range of compositional variations (Table S10). Generally, serpentine is characterized by higher Fo value (96.3-98.2), SiO_2 (47.3-49.7 wt.%), Al (1079-8548 ppm), Ca (94-5346 ppm), Ti (63-273 ppm), and Na (61-247 ppm), and lower FeO (1.61-3.22 wt.%), MgO, and Co (77-106 ppm) contents than olivine, which reflects the alteration reworking. Moreover, the composition of olivines in our samples is comparable to those of fresh olivines in other typical komatiites (Extend Data Fig.3 and Fig. 4), so we confirm that its oxygen isotopes represent the primary characteristics. these trends are consistent with previous observations.

In some cases, olivine may first undergo alteration to form serpentine, and then form olivine again due to dehydration during high-grade metamorphism (Peters et al., 2020 EPSL; Nutman et al., 2021 PR). The metamorphic grade of Weltevreden komatiites is mainly greenschist facies, and olivine in this case inherits the compositional characteristics of serpentine, especially the extremely high Fo values (96-98) (Nutman et al., 2021 PR), which do not correspond to the olivine in our sample.

We add this discussion in section 4 Effect of alteration on olivine in the supplementary materials Line 112-130. We also add the composition of serpentine in Table S10.

L38: Gamaleldien et al. 2020 SR, can be added to the subduction part.

Revised

L52: Add reference, please. Valley work?!

Revised

L130-133: Can you add a supp figure to show those geochemical relationships?

Revised. Actually, Fig. 3 and Fig. 4 in Puchtel et al. 2013 GCA (ref. 9) have shown the variations of major, minor, and trace element abundances as a function of MgO in binary diagrams. Also, in our Extend Data Fig. 2, Fo content versus first-row transition elements (FRTE) for olivine grains, the occurrence of an inflection point in the Fo versus Cr diagram implies the co-crystallization of minor Cr-rich chromite in the low- $\delta^{18}\text{O}$ group.

We add an Extend Data Fig. 2, a binary diagram of some representative elements with MgO contents for our samples. a) CaO; b) Al_2O_3 ; c) TiO_2 ; d) V; e) Ni; f) Nb; g) Sc; h) Y; i) Hf as a function of MgO in Weltevreden komatiite samples.

L195-200- How you did do this estimation and assumptions? Can you develop this model using Monto Carlo modeling?

We want to estimate the fraction of recycled oceanic crust contribution based on oxygen isotope composition, so we need two end elements. One end element is the normal mantle, and the other is the oceanic crust undergoing high-temperature alteration. Since so little of the Archean oceanic crust is preserved, we analogize the oxygen isotope values of the Archean oceanic crust based on the $\delta^{18}\text{O}$ values in modern altered oceanic crust and mantle eclogites. The main factors controlling the $\delta^{18}\text{O}$ values of high-temperature oceanic crust are the $\delta^{18}\text{O}$ values of Aechean seawater and the ratio and intensity of high-temperature and low-temperature alteration. The oxygen isotope composition of ancient seawater is a matter of great controversy. Different studies have yielded different results, with some suggesting that the $\delta^{18}\text{O}$ values of ancient seawater were lower than those of modern seawater (Galili et al., 2019 Science, based on the $\delta^{18}\text{O}$ record in marine iron oxides; Guo et al., 2022 EPSL, based on a comprehensive model of solid Earth evolution coupled to a mass balance model of seawater oxygen isotope ratios), others coming to the opposite conclusion (Johnson and Wing, 2020 Nat. Geosci), and still others suggesting that seawater's oxygen isotope values have been stable since the Archean (Peters et al., 2020 EPSL). The main factors controlling the variation of $\delta^{18}\text{O}$ values in seawater are water-rock interactions with rocks at different temperatures and weathering inputs following continental uplift above sea level.

Here, based on the oxygen isotope compositions of modern altered oceanic crust (as low as -2 ‰, Gao et al., 2012 G-cube) and mantle eclogite xenoliths (the $\delta^{18}\text{O}$ values as low as 2 ‰; mantle metasomatism and the sum of processes in subduction zone are mainly responsible for the alteration of the initial $\delta^{18}\text{O}$ value, the extreme contribution of mantle metasomatism is not more than ± 2.5 ‰, with the typical deviation

not $>1.2\text{ ‰}$; Korolev et al., 2018 ESR), In addition, garnets with $\delta^{18}\text{O}$ of $<4.5\text{ ‰}$ were mainly found in mantle eclogites from the Kaapvaal Craton (22.3 % of samples, a total of 157 samples), which describes its specificity (Korolev et al., 2018 ESR).

We tend to think that the oxygen isotope values of Archean seawater are lower, and the proportion of high-temperature hydrothermal alteration may also be higher in the Archean, which will lead to the high-T altered oceanic crust with lower oxygen isotope compositions. Therefore, we suggest that we chose 0-2 ‰ as the oxygen isotope value for Archean high-T altered oceanic crust here is reasonable.

L231-234: Please add RFF: Gamaleldien et al. 2020 SR

Revised

Decision letter and referee reports: second round

27th Nov 23

Dear Dr Ouyang,

Your manuscript titled "Low- $\delta^{18}\text{O}$ deep mantle reservoir reveals oceanic crust subduction before 3.3 billion years ago" has now been seen by our reviewers, whose comments appear below. In light of their advice we are delighted to say that we are happy, in principle, to publish a suitably revised version in Communications Earth & Environment, provided you move the discussion points that are currently in your rebuttal letter into the manuscript itself and ensure the terminology you use throughout the manuscript is consistent. If suitable, we will publish the revised manuscript under the open access CC BY license (Creative Commons Attribution v4.0 International License).

We therefore invite you to revise your paper one last time to address the remaining concerns of our reviewers. At the same time we ask that you edit your manuscript to comply with our format requirements and to maximise the accessibility and therefore the impact of your work.

Please note that it may still be possible for your paper to be published before the end of 2023, but in order to do this we will need you to address these points as quickly as possible so that we can move forward with your paper.

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Decision letter and referee reports: second round

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Best regards,

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REVIEWERS' COMMENTS:

Reviewer #1 (Remarks to the Author):

I have examined the revised version against the two reviews, finding that the authors have only done partial revision but quibbled some important points. Typically, only minor Archean komatiites show low d18O values, so do Archean TTG rocks. The occurrence of low d18O TTG rocks is evident in the Paleoproterozoic, indicating the existence of low d18O residues in the lower crust. If such low d18O residues could be delaminated into the asthenospheric mantle, they would contribute to the local production of low d18O mantle lithology. If the SCLM would be depleted in 18O, it could be assimilated by komatiitic magmas to acquire the low d18O signature. However, the present study shows that the low d18O olivines exhibit lower SiO₂ contents and higher FeO contents than those in the normal d18O olivines, pointing to the existence of low d18O peridotite in the deep mantle. It is possible that the low d18O peridotite would be produced by metasomatic reaction of normal d18O peridotite with low d18O basaltic melts in connection to recycling of the deeply subducted high-T seawater-hydrothermally altered oceanic crust in the Paleoproterozoic.

In addition, the authors have confused between a number of professional terms in their discussion, such as magma assimilation vs crustal contamination, crustal eclogite vs mantle eclogite, and the composition of pyroxenites in silica-excess vs silica-deficient. The crust can be assimilated by a basaltic magma, and the basaltic magma can be contaminated by the crust. However, it is not the crust to be assimilated by the magma. Eclogites were produced either by the metamorphism of basaltic crust or by the accumulation of basaltic minerals, resulting in crustal eclogite and mantle eclogite, respectively. The silica-excess pyroxenite was generated by the chemical reaction of peridotite with felsic melts, whereas the silica-poor pyroxenite was produced by fractional crystallization of pyroxenes from basaltic magmas. Their partial melting gives rise to andesitic and basaltic melts, respectively.

In view of the above arguments, I am not able to recommend this paper for publication in the present form. A major revision is necessary before any further consideration.

Reviewer #2 (Remarks to the Author):

Thanks for considering my comments. I don't have any more comments. Good luck with the publication process.

Regards,
Hamed Gamaleldien & Environment.

Author Responses: second round

We thank the reviewers for their comments.

Reviewer #1 (Remarks to the Author):

I have examined the revised version against the two reviews, finding that the authors have only done partial revision but quibbled some important points. Typically, only minor Archean komatiites show low d18O values, so do Archean TTG rocks. The occurrence of low d18O TTG rocks is evident in the Paleoarchean, indicating the existence of low d18O residues in the lower crust. If such low d18O residues could be delaminated into the asthenospheric mantle, they would contribute to the local production of low d18O mantle lithology. If the SCLM would be depleted in 18O, it could be assimilated by komatiitic magmas to acquire the low d18O signature. However, the present study shows that the low d18O olivines exhibit lower SiO₂ contents and higher FeO contents than those in the normal d18O olivines, pointing to the existence of low d18O peridotite in the deep mantle. It is possible that the low d18O peridotite would be produced by metasomatic reaction of normal d18O peridotite with low d18O basaltic melts in connection to recycling of the deeply subducted high-T seawater-hydrothermally altered oceanic crust in the Paleoarchean.

In addition, the authors have confused between a number of professional terms in their discussion, such as magma assimilation vs crustal contamination, crustal eclogite vs mantle eclogite, and the composition of pyroxenites in silica-excess vs silica-deficient. The crust can be assimilated by a basaltic magma, and the basaltic magma can be contaminated by the crust. However, it is not the crust to be assimilated by the magma. Eclogites were produced either by the metamorphism of basaltic crust or by the accumulation of basaltic minerals, resulting in crustal eclogite and mantle eclogite, respectively. The silica-excess pyroxenite was generated by the chemical reaction of peridotite with felsic melts, whereas the silica-poor pyroxenite was produced by fractional crystallization of pyroxenes from basaltic magmas. Their partial melting gives rise to andesitic and basaltic melts, respectively.

1. We have revised the inappropriate use of terminology raised by the reviewers. They mainly include 1) crustal contamination and magma assimilation (see in text); and 2) the use of “pyroxenite”. The term “pyroxenite” is used here to refer to a broad sense (Sobolev et al., 2007; Lambart et al, 2013, 2016). We only want to emphasize that it is a source region distinct from normal mantle peridotite, i.e., a source region formed by reactions between recycled materials (including oceanic crust) and mantle peridotite. The reactions between recycled oceanic crust and mantle peridotites are very complex and result in a range of mantle source regions with different compositions (Neave et al., 2018). Now, we replace “pyroxenite” with “pyroxene-rich lithologies” to reduce ambiguity.

2. The reviewers emphasize that part of the lower crust may have a low- $\delta^{18}\text{O}$ signature, and the recycling of these melt residues into the mantle can lead to low- $\delta^{18}\text{O}$ lithospheric mantle regions. We assessed this scenario (assimilation of lithospheric mantle material) in Lines 158-168. The relatively low Fo values of olivines with low

oxygen values are not low and are comparable to those of other komatiites worldwide (Supplementary Figure 2). Instead, olivines with normal $\delta^{18}\text{O}$ values have extremely high Fo values, which may reflect anomalously high melting temperatures. If it is produced by the metasomatic reaction between normal peridotite and low $\delta^{18}\text{O}$ basaltic melts, its Fo value will be conspicuously lower (Xu et al., 2021). Additionally, it is important to examine the compositional variations of olivine in a single sample/grain, which are similar to those found in kimberlite (Giuliani et al., 2018; Soltys et al., 2020; Xu et al., 2021; Line 157-164 in main text). These effects arising from incomplete reactions are anticipated due to the rapid emplacement rate of komatiitic magmas with high temperatures and low viscosity (Line 253-254). However, oxygen isotope and trace element compositions of olivine in a single sample/grain are very homogeneous. The different evolutionary trends between oxygen isotopes and trace element elements are also not explained by this mechanism. In addition, the extremely negative δD values of the melt inclusions in olivine (recording the pristine magma compositions; Sobolev et al., 2019) suggest its source feature rather than products of metasomatic reaction. These two types of komatiites must have originated from two different source regions.

3. The type and genesis of eclogite are beyond the scope of this paper and do not affect our discussion. Many researchers believe that a model of mantle eclogite origin by the transformation of oceanic crust is very convincing and has now reached the status of a dominant paradigm (Korolev et al., 2018). Although other origin models for mantle eclogite exist as well. Whether they are crustal or mantle types, during the processes of recycling back into the mantle, many factors (including dehydration, metasomatic alteration, partial melting, metamorphic reworking diffusive fractionation, hypergenesis, and mantle metasomatism) do not cause large oxygen isotope fractionation, based on the similar range of oxygen isotope compositions between mantle eclogite and subducted oceanic crust (Korolev et al., 2018). Here, we only mentioned mantle eclogite once (didn't even mention crustal eclogite) and want to stress that the fractionation of its oxygen isotope values during subduction was limited ($<2\text{‰}$). Then we can use the $\delta^{18}\text{O}$ values of mantle eclogite (low $\delta^{18}\text{O}$ values part) to estimate the $\delta^{18}\text{O}$ values of the high-T altered recycled oceanic crust.

In conclusion, based on the compositions of whole-rock and olivine grains, we aim to show that low- $\delta^{18}\text{O}$ komatiites have not been influenced by low- $\delta^{18}\text{O}$ materials during emplacement, emphasizing the low- $\delta^{18}\text{O}$ nature of their source regions.

Other major revision

Rewrite the discussion of crustal contamination, and make it more concise. Now in Lines 146-157:

When crustal contamination and hydrothermal alteration occur, it is expected that komatiitic lavas would exhibit lower eruption temperature, elevated lithophile trace element abundances (such as Ba, Th, U, Zr, and LREE), and trends of decreasing $\delta^{18}\text{O}$ with decreasing Fo, MgO, and Zr/Nb, along with an increasing in $(\text{La/Yb})_{\text{N}}$, Sm/Yb , Ba/La , and Ba/Li^{28-30} . However, the observed geochemical characteristics in Weltevreden komatiites contradict these expectations, with extremely low

concentrations of Ba and Th, and uniform LREE depletion (Supplementary Fig. 5), indicating no disturbance of incompatible elements. Additionally, the $\delta^{18}\text{O}$ values do not show a correlation with these crustal contamination parameters (Supplementary Fig. 6). These distinctive geochemical characteristics of olivines and host whole rocks effectively rule out crustal contamination as the cause of the low- $\delta^{18}\text{O}$ values in parental Weltevreden komatiite melts.