Here we reply to the comments of **Ortolano-Referee #2**. We reported in Italic the Ortolano-Referee #2 text. Note: at the end of the document "Reply to Anonymous Referee1" are available two new sections and a new figure that will be added in the revised manuscript, according to our replies to the two referees.

Summary statement

- *Although the work presents high-quality analytical data, unfortunately, the manuscript does not have a clear focusing line. It seems often a description of samples without sufficient context to allow the reader appropriate information to assess the processes proposed. The problem starts from the sample selection strategy. This is indeed not sufficiently justified to underline the specific peculiar features useful to better highlights the different mechanisms of garnet overgrowing stages developed during the Alpine evolution.*

Thanks for these suggestions: We will strengthen the Introduction, stating more clearly the specific goals of this paper. In the revised version, we will also change the name of Section 4 in "**4 Sample selection strategy and petrography**", we shall include a paragraph on important aspects of our sample evaluation strategy.

- *It is out of sense for instance, during discussion, uses the name of the sample to describe the specific textural characteristics of the related Alpine garnet overgrowing stages. For an external reader, a name is a name. Instead, should be better associate a name to a specific process.*

We understand that the sample names we use have no meaning to an external reader, but we think that keeping them in the text is important and fundamental to be able to discuss the different processes in the light of the garnet textures. Such textures have some similarities amongst samples but also remarkable peculiarities and differences. Without referring to the sample names, specific observation and discussion would result hard or impossible to follow to an external reader. It would also diminish the possibility of the reader to self-asset the interpretation of such textures and it would render the discussion section much more subjective to the eyes of an external reader. Furthermore, to give more result to the processes and less to the samples names, we already grouped the different processes as is visible from the different subsection of section 6 (**6.1 Micrometre-size fracture network in garnet cores, 6.2 Resorption and growth: fluid-related textures, 6.3 Re-equilibration close to fluid pathways**) and discussed similarities amongst samples for each of these. Finally, this sample series is part of other publications; some of these are already published and have this sample nomenclature: changing it would results to confusion and would damp comparison of the data.

- *Moreover, during in the introduction as well as in the discussion, were not taken into account any alternative possible interpretation for justifying the observed garnet texture. For instance, some brittle behavior can be generated not only by a high strain rate in non-coaxial regime but also by plastic-to brittle transition with the formation of a fractured mesh that might represent evidence of past episodic tremors or "slow earthquakes" triggered by high pore fluid pressure (Malatesta et al., 2017 Geological Magazine). What other evidence have the authors to justify their interpretation?*

This comment seems partially unfounded: In the Introduction, we outline three possible interpretations of the garnet textures reported in the literature from the Sesia Zone (page 2 lines 19-32); alternative processes leading to the formation of atoll garnet are presented (page 2 line 32, page 3 line 4). Furthermore, we propose two alternatives processes to account for the development of fractures (page9 lines 15-24). For reasons outlined in section 6.1 we favour the first interpretation. It is correct, however, that we can improve the discussion section by stressing which data and textures support or confute alternative interpretations (as referee#1 also commented).

Regarding the specific suggestion *(following Malatesta et al., 2017)* of *tremors or "slow earthquakes" triggered by high pore fluid pressure* possibly leading to brittle behaviour, we think that this situation applies to our dataset: The interpretation by *Malatesta et al.* is based on lithotypes with strong rheological contrast, i.e. metasediments alternating with metabasites, separated by cm-thick talcschist layers, so metabasite shows brittle fracturing (boudinage, brecciation) inside the weak matrix (Fig.4, 14). In our samples, brittle fractures are observed in garnet (and zircon) cores, which are relics of a dry granulite that must have been mechanically strong. We see strong analogies in our situation with the fracture patterns and compositional maps of garnet reported by Austrheim et al., 1996; Angiboust et al., 2012 and Austrheim et al., 2017. These authors interpreted such textures as produced by high strain rates related to seismic failure. For this reason we tentatively adopt such an interpretation to explain the features we observed in garnet (page 9 lines 9-11).

- *Finally, in my opinion, the potentiality of the quantitative data extrapolation from image analysis by X-Map tools, was not satisfactory, in term for instance of the extrapolation of the effective reactant volumes of the single observed paragenetic equilibria. This can be useful to better constrain the ab initio*

parameters useful for a more consistent thermodynamic modeling, which unfortunately, was not described in the manuscript.

As in our reply to Anonymous Referee #1 comments, these data are part of the companion paper "Deeply subducted continental fragments: II. Insight from petrochronology in the central Sesia Zone (Western Italian Alps)" currently under review in Solid Earth and fully accessible. We agree that these data are necessary to support our interpretations, but the volume and diversity of material is such that we decided to present it in companion papers. In the present manuscript, wherever data are particularly critical for our interpretation, we refer the companion paper (as Giuntoli et al., submitted). However, since both Ortolano and Referee#1 had difficulties to see the connection and asked for some clarification on methods we used, a section (**5.2 Modeling phase equilibria in partially re-equilibrated rocks**) will be introduced in our revised version to explain our approach to thermodynamic modeling of garnet.

- *For all of the above reasons, the manuscript requires a deep major revision, consisting in a substantially rewriting of the introduction and of the discussion part, focusing the attention for instance to the use of the image analysis in the calculation of the effective bulk rock chemistries for the single extrapolation of paragenetic equilibria. Moreover, it is fundamental a better presentation of the complete methods utilized, together with a greater contextualization of sample selection.*

We propose to improve the Introduction according to Ortolano's comments. For the use of image analysis in approximate effective bulk rock compositions from local composition, but we do not believe that this is necessary in this paper. The bulk rock composition was used for modelling, this is quite common and the good results of the models partially justify this assumption. The reproducibility of the zoning pattern at the centimetre scale also supports this assumption. It is thus not necessary to define a smaller equilibration volume that is also not supported from a textural point of view. The garnet composition is for instance the same in the phyllosilicate-rich layers and in the quartz-rich layers supporting the grain boundary equilibrium model assumed here. All these points are already discussed in some details in Lanari et al. (2017), presenting the GRTMOD program. A new modelling section with some computational details will be introduced in the revised manuscript (see previous comment). As stated above, we shall also add a section regarding the sample selection (collection and evaluation) strategy we used.

Specific comments (from Ortolano's pdf supplement file)

- *It is a zoning or an overgrowing crystallization*

To avoid misinterpretation at this stage, we prefer the "zoning" as a purely descriptive term.

- *Local texture and mineral chemistry are combined to define the ab inition constraints for a more consistent thermodynamic modelling. This last is function of the textural and mineral chemical features of the specific paragenetic equilibria*

Rephrased according to this comment.

- *Please introduce the sample selection logic, before to describe the chracteristic of the single sample. The sentence is not so clear, please rewrite.*

This is good advice and, as stated in the summary statement, we will adopt it.

- *This is the unique solution?*

See the above discussion in summary statement

- *Please emphasize that the thermodynamic modelling was assisted by quantitative image analysis useful to extrapolate the effective bulk rock chemistries of each paragenetic equilibria*

Ok, we introduce some details about modeling in the main text, as stated above

- *A robust thermodynamic modelling derives from a quantitative extrapolation of the effective reactant volumes of the single metamorphic evolutionary stage*

We present this topic in the new section about modeling

- *How many samples with what logical selection*

As above, we introduce this in the section on sample selection strategy

- *This is an anticipation of the discussion. Please avoid it.*

Ok, deleted.

- *How many thin sections. What is the logic of sample collection and more in particular, what is the logic of sample selection of those sample used for the thermodynamic modelling?*

We add this in the section on sample selection strategy

- *Please specifies better the logical meaning of the proposed procedure and the specific results that the authors want to reach for the aims of the present work.*

Ok, we will add such details, as well in the new section **5.2 Modeling phase equilibria in partially re-equilibrated rocks** that will be added in the revised version.

- *Also in this case, please specifies the logical meaning at the base of the use of XMapTools, such for instance to unravel the effective bulk rock chemistries of the modelled systems and so on.*

This will be presented in the new section **5.2 Modeling phase equilibria in partially re-equilibrated rocks** that will be added in the revised version.

- *Please specifies the logical process of the sample collection campaign and the following logical meaning of selection of those samples considered characteristic of....(e.g. Alpine prograde metamorphism; Retrograde Variscan metamorphism and so on...)*

Yes, we introduce this in the section on sample selection strategy.

- *More than a compositional zoning, I would talk about Evolution of the garnet overgrowing stages*

We consider this suggestion as a good alternative

- *This fractures are very intersting. Just for suggestion, if you use the X-ray Map Analyser (Ortolano et al., 2014 C&G), you can probably extrapolate the specific principal component of the classified image which correspond to the different generation of sealed fractures.*

That's correct, and in fact we followed this suggestion but using XMapTools; the results are presented in section 5 (e.g. page 6 line 13). A clarification: we see one generation of fractures sealed by garnet, a second generation is cutting across all of the garnet growth zones with chlorite lining. This is related to the retrograde greenschist stage, a late metamorphic phase evident in many parts of the Sesia Zone.

- *Principal Component Analysis indeed can highlight the specific interdependence of the different elemental components, emphasizing the presence of specific subphase, using the second analytical cycle of X-Ray Map Analyser.*

Ok this is true, but it can also be achieved in a simple binary chemical diagram, as only two chemical variables are independent in this case (XAlm and XGrs for instance with XPrp being dependent).

- *It is out of sense indicate a subparagraph of the manuscript with a samèle name. An external reader would understand the specific significance of that sample.*

Not sure we understand this comment. This hierarchy in fact aims to help readers to follow the presentation of the data. Possibly we could change a (sub)heading.

- *Where is the thermodynamic modelling approach. How it was calculated the Effective Bulk Rock chemistry of each garnet overgrowing stage.*

See our summary statement: A summary of the approach will be added to the revised manuscript. Note that the effective bulk composition is part of the optimization function to be able to predict fractionation or resorption (see Fig. 3 and 4 in Lanari et al. 2017)

- *Discussion have to be rewrite to better focus the aims of the paper, taking into account previous or potential different interpretations, supporting the present one with more consistence.*

The revised Discussion will take this suggestion into account (in line with the comments of Referee #1).

- *The shape of the bounday for the study area identification not seem to be the same of the Fig. b.*

The shape of the study area is not exactly the same in the two maps due to graphic reasons and the big difference in the map scales, nonetheless it is representative

- *What is c*

Mistake corrected

- *To thick*

Ok, reduced

- *This image should be better emphasized with the use of the principal compoent analysis*

See our previous reply to the specific comment on "*Principal Component Analysis*"

- *These images should be better emphasized with the use of the principal compoent analysis*

See our previous reply to the specific comment on "*Principal Component Analysis*"

- *This figure look very good*

Thanks

We thank G. Ortolano-Referee #2 for his constructive comments.

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