Answer to the comment https://doi.org/10.5194/egusphere-2022-949-RC1, 2022

First, the co-authors would like to thank the Anonymous Referee for its thorough comments on the manuscript.

All the modifications suggested regarding the typo have been done directly in the text.

I read this work with great interest. The starting hypothesis of recognizing a signal of pre-collisional thermal events through the use of geothermometers in an external sector of the chain (where therefore the Alpine metamorphism may not have overprinted everything) seems interesting and promising, possibly providing important contribution to the reconstruction of the pre-Alpine paleogeography evolution of this sector of the Paleo-European continental margin.

However, I believe that a lot of work still needs to be done in order for it to be published. Some important points need to be addressed by the authors; among these, the most important concern the controversy on the nature and timing of the Valais oceanic domain (ignored by the authors) and the fact that the high temperatures presented in this work should imply, in my opinion, some evidence of metamorphism, in a domain which is, on the contrary, commonly described as non-metamorphic (in my extended comments below you will find much more comments on these points).

Furthermore, in many parts the data presentation can be improved, making it more organized and understandable. In the Interpretation and Discussion sections some sentences are a little obscure and hard to understand, and some points deserve wider explanations and discussions. I got the impression that it was written a bit in haste, without the necessary accuracy and without providing a deep and complete discussion of the reliability of the measured data and of their geological meaning in the Alpine geological context.

For these reasons I think that the manuscript in its actual version can not be published, and recommend major revisions.

Abstract

Lines 14 to 17: you should better specify where the samples come from. The expressions "along the Digne nappe" or " the nappe stack" are too generic

L 14 and 17: We have added complementary informations on sample location.

Introduction

Line 30: no comma needed after "crustal structure"

L 30: Done.

Line 49: the sentence "…together with issues realted to the magnitude of continental collision" is too generic, you must specify and/ore quote some papers

Line 51: Why "Although"? The second part of the sentence is not in contrast with the first…

Line 49 and 51 : Corrected. We have reorganized the introduction and reformulate some of the sentences.

Line 54: "carrying": better "Characterized by"; why "..a thick Jurassic syn-rift section"? The Digne nappe is not made up of uniquely Jurassic successions....
Line 54: Modified.

Line 56: what do you mean with "pre-collisional stratigraphic series"? The successions (succession is more appropriate than serie) underlying the Alpine Foreland one? But in some cases you sampled up to the Eocene.....
Line 56: We have replaced "series" by "successions" and modified the text to clarify the position of the studied stratigraphic units relatively to the nappe emplacement and other main stages of the tectonic evolution of the margin.

Geological Setting

The authors write about two rifting events, stating that in the Late Jurassic – Early Cretaceous the Valais ocean opened. They describe this in few words, as it was a fact, well documented and acknowledged by all the geological community. But it really is not. There has been a long controversy on the Valaisan, and still there is, that concerns its nature of oceanic basin, its extension, and its timing. The Authors quote the paper by Beltrando et al., 2012, but they do it inappropriately. Beltrando et al. dedicated a lot of space to reviewing the debate concerning the Valais (not by chance the title of the paper start with "The Valaisan controversy revisited..."), and in the discussion they interpreted they original data suggesting that "the crustal thinning in the Valaisan basin may have been kinematically linked with the opening of the Western Tethys" (thus not in the Cretaceous!). Geochronological data are scarse and often contrasting (e.g.: Liati et al. 2005), and many Autors provided a large body of structural and stratigraphic evidence pointing to a Jurassic opening of the Valaisan basin, even in recent papers (see for example Mohn et al. 2010, Ribes et al., 2019, 2020). This is not my research field, and I can not say if the Valais opened in the Jurassic together with the Western Tethys or later in the Cretaceous. But the authors can not ignore that it is still a highly controversial topic, and should report and comment on this. Actually, if the authors introduced it adequately, the data resulting from this paper could give a new contribution to such problem!

We agree with the reviewer. We have reworked this part. The formation of the Valaisan domain, based on existing geochronological and field constraints can broadly agree with the timing of the formation of the Western Tethys. But it also recorded subsidence, magmatism/metamorphism during the early Cretaceous. We therefore emphasize that the European margin is the result of a long lasting evolution since the early Jurassic marked in the Valaisan Domain by an early Cretaceous thermal/metamorphic and magmatic event.

Lines 63 to 78: the first sentence is not clear, should be rephrased. In general, the description is not always linear (see for example line 68, with an abrupt jump from the second rift event to the continental breakup, which however is referable to the first one). And the 33.9 Ma age seems to me too precise.... Do the quoted papers really indicate it for a long-lasting event such as the transition between two collisional stages?
L 63 to 78: We reorganised and corrected the text.

Line 81: "hangingwall" is unnecessary
L 81: Modification done.

Line 84: "It turns..." refers to the main thrust. But in the previous sentence you were referring to the Digne nappe.... Please rephrase.
L84: rephrased.

Line 85: A nappe is not a thrust front….
L 85: We keep nappe and corrected the rest.

ines 85 to 88: please use succession instead of serie. A description of the succession should be provided. It can be brief, but I think it is necessary, since you collected your samples all over it.
L 85 to 88: modifications done through the text. We added a brief description of the dominant lithologies.

Samples and Methods
RSCM Thermometry along reconstructed vertical sections

This section is definitely incomplete and bad organized. As general comments I would say that authors should first of all briefly explain what RSCM thermometry is and how it works, since this journal is not uniquely dedicated to Raman analysts (and please, the first time you cite RSCM wrote it in the extended version). They should then describe which was the goal of the sampling and analysis, and provide a lithological (and possibly a petrographic one too) description of the samples (they wrote carbonate deposits: too generic, I guess thay should be CM-rich rocks…. Are all limestones or shales too?). And some description of the analytic instruments and their operating conditions must be provided. Lines 105 to 112 do not refer to the methods of this work and should be moved to the Results or Discussions sections.

The first time we cite RSCM is in the Abstract and we wrote it in its extended version. We thus did not modify this in this part of the text.

We added a paragraph stating what RSCM thermometry is and which material has been used.

We also moved the paragraph from L 105 to 112 in the Results section.

Line 97: the first time please write the name of the sections in the extended version. The same in the legend of figure 1B
L 97: done.

Lines 100 to 102: This sentence ("Because the nappe…. prior to thrusting") is definitely not clear, please rephrase
L 100 to 102: Agreed. We modified the sentence.

Lines 105 to 109: too long sentence, better to split in 2 or 3. The statement "during the passive margin stage coeval to crustal thinning" is wrong: the passive margin stage goes on well after the end of the crustal thinning.
L 105 to 109: modified for more clarity.

Lines 109 to 112: This is an important point for interpretation of your data and I think deserve more explanations. Anyway, not in this section (see comment before)
Agreed.

Numerical modelling with basin model

Line 116: "temperatures across the Digne thrust front.." did you mean along?
L 116: yes we did, we modified.

Line 117: convert in place of converted

L 117: We modified the sentence.

Line 118: I do not understand "burial in the Alpine foreland"... In this scenario the Tmax is achieved due to the unique effect of the burial history. But during the entire burial history...
L 118: Yes we clarified this in the text.

Line 120 and line 124: some values of the crust and lithosperic mantle are reported. How did you chose them? At least some citations are needed.
L 120 and 124: This is now better presented in the revised version. We have chosen initial boundary conditions, prior to lithospheric thinning, as follows, 30 km for the crust and 90 km for the mantle lithosphere. These values are typical for the post-Variscan lithosphere (e.g. Mouthereau et al., 2021).

Lines 125 to 130. All this explanation is not completely clear, particularly the last sentence. How could you reconstruct the thickness of the Cretaseous sediments eroded during the formation of the Foreland basin unconformity starting from the AFT data in the Miocene deposits? Please try to better illustrate your reasoning
L 125 to 130: We rephrase this part. We do not use AFT ages in the Miocene to reconstruct the Cretaceous. We have estimated for DEV, SLC, and CLN sections the amount of eroded Cretaceous (coherent with what is observed in surrounding areas where it is not eroded) and the 3 km of Cenozoic which is eroded as well.

Line 141: Why did you chose to fix the T at 1333 °C? And which is the reason for a such specific value? It is an assumption, so I do not understand which is the meaning of a such specific value. I mean, 1350 would be uncorrect? Why?
L 141: This value corresponds to the temperature below which heat is lost by conduction which is also the definition of the lithosphere. We rephrased this sentence.

Line 149. In which locations of the SW Alps is reported this thickness of Middle Triassic limestones? In many places (e.g. External Briançonnais) the Middle Triassic is much more thick....
L 149: This is the thickness of the Middle Triassic reported in the Verdaches area just to the North of the Barles half window, at the base of the Digne Nappe which is the study area. This value is reported from the "La Javie" geological map at 1/50000 (Haccard et al., 1989) which mentions a multi-decametric thickness of Middle Triassic limestones in Verdaches.

Results
RSCM Temperatures

Line 155: "Domain"?? I would replace with trend
L 155: We already used the term "trend" for the temperatures. We use the term "domain" when we talk about locations along the "vertical" sections.

Evidence for rift-related thermal event

Some major points corcernings this section.

It contains a discussion of the RSCM results, and thus in my opinion it should be moved to the Discussion section.

You found very high Temperatures, up to 340°, in the Early-Middle Jurassic beds of the most of the sections. These temperatures are commonly considered to be in the range of metamorphism. Low grade metamorphism (green schist facies), but metamorphism. In the Discussion below you propose an interpretation in which such thermal perturbation is related to two rifting events: this means that such perturbation lasted for tens of million of years. I would expect that sedimentary rocks affected by temperatures above 300°C for such a long time interval in an extensional setting (in which the fluid circulation through the crust is highly favoured) would be transformed in metamorphic rocks. At least they should bear evidence of recrystallization and neo-blastesis. And I guess that many of your samples are shales or rocks with a shaly component, that is the most reactive to metamorphic reactions. You should face this point by providing a petrographic description of your samples. In the case you can not find any evidence of recrystallization and neo-blastesis you should propose a mechanism that hampered these processes at such high temperatures. I am not an analyst or a Raman expert and I do not want to doubt about the RSCM method; but I know that there has been (and probably there is) debate around it. Some authors reported kinetic effects and the occurrence of metastable poorly crystallized graphitic carbon that, in their opinion, would affect the reliability of the RSCM geothermometer (see for example Foustoukos 2012, American Mineralogist). All the more reason you should describe the rocks you analysed, showing the differences between the ones in the upper part of the sections which not experienced high temperatures and the ones in the lower part which were affected by temperatures up to 340°C. Alternatively, if you could not find any evidence, you should discuss how it was possible, in order to exclude that such temperatures are "fake" temperatures due to analytical artefacts.

Line 168. "(para-) autochtonous" I would avoid this old and ambiguous terms: you could more simply use "AFT ages from the Eocene sediments of the Digne nappe"
L 168: we modified as suggested.

Lines 173 to 175: I got your reasoning but I think you could make it a bit more explicit
L 173 to 175: We have elaborated on this and added a sentence to better explain our reasoning.

Line 174: Figure 2C, not 2B
Corrected.

Lines 177-178: see comment before too. Why do you talk about syn-orogenic burial? I would say that T values in the CAS section are consistent with a normal and continuous burial history (fromt Triassic to Pliocene)…
L 177-178: Yes, but please note that in this section we present the main characteristics of the RSCM temperatures before TemisFlow modelling. For CAS, temperatures are below 150°C. Given the thickness of the foreland basin sediments and a gradient of 30°C these temperatures could simply reflect burial in the foreland. We have modified the text to make it clearer.

Results of numerical modelling

Line 185: did you mean figures 4 and 5? In figure 3 results from all the three models are shown
L 185: We start with Figure 3 which present a comparison of predicted and observed temperature of all the models (3 scenarios). Figures 4 and 5 correspond to the results obtained for the Two Rifts model only.

Lines 195-196: "deepest sediments": which sediments are you referring to? The ones below 2 Km? In this case I would say between 230-340°C, not above
L 195-196: modified as suggested.

Lines 205 - 209: This is not convincing at all! The CAS section is just 24 km from the CLN section, and owns to the same tectonic unit and the same paleogeographic domain. Moreover, you can not desume a more internal location from the described difference in thickness of the Jurassic succession (and in figure 6 you do not locate it a more inner position….). Continental rifted margins are characterized by significant and abrupt changse in thickness of the syn-rift sediments. In the Dauphinois domain see for example the Ornon fault area (Chevalier et al 2003, and their figure 1c); the Briançonnais domain is characterized by a reduced and condensed Jurassic succession, but it pertained to a much more external position with respect to the study area of this work. I think that another explanation must be given for the "colder" values of the CAS section.

L 205 – 209: Note that in the study area the relationships between the syn-rift strata and its basement are not documented because the Upper Triassic evaporites have been decoupled during extension and involved in salt tectonics since the Early Jurassic. The facies and the thickness of the syn-rift strata in the Castellane are completely different from the ones in the northernmost area of the Digne Nappe which was located in the deeper part of the Digne-Gap basin during the Mesozoic (see Baudrimont & Dubois, 1977). However, it is true that the burial history looks very similar we therefore chose to adopt the same Two Rifts interpretation.

Lines 210 - 215: This is an important point and deserves much more attention. What are the 3D effects? And the kinetics of organic matter maturation? You simply mention these aspects, but I think you should comment them. Some authors do not consider the RSCM geothermometer reliable because of some of these problems (see my comment above): you should comment more extensively.

L 210 – 215: Thanks for this comment which lead us to look more carefully at existing data in the SW Alps. We are aware of the current debates on the importance of pressure and deformation on the reliability of RSCM geothermometer. The kinetics of organic matter maturation should also be taken into account when we interpret those data. We think that these temperatures are broadly in agreement with other previous publications in the region, specifically within the Jurassic "Terres Noires" which outline the significant role of fluid circulation during the Cretaceous. We have tried to make those points clearer in the new version. We think that the robustness of the rscm data is not in question and that it can be explained by other mechanisms such as the presence of fluids.

Discussion

Tmax explained by decoupled crust-mantle

Lines 219 to 226: such a huge lithospheric stretching and very high geothermal gradients should have a large body of evidence, even in the syn-rift stratigraphic successions (paleofaults, hydrothermal products, abrupt thickness changes, large breccia bodies, etc.…). Actually some of these evidence have been reported in literature for the Early cretaceous too, both in the Dauphinois Domain and in the adjoining Brianòonnais Domain. I think you should consider this.

L 219 – 226: We have provided more details from the literature in the discussion.

Lines 229 to 231: It is not clear which is the old proposed position of the Digne nappe and your new interpretation. Do you think it corresponded to a hyper-thinned domains? And why it should have been located on a transfer zone?

L 229 – 231: We removed this sentence. The existence of the transfer zone is now well accepted in communnity as indicated by the recent papers (Ribes et al., 2019;2020 ; Dall'Asta et al., 2022) and was actually first mentioned by Lemoine et al. (1989). The justification is first based on the difference of extension between the Vocontian and Valaisan domains, the fact it is parallel to extension direction and that the Valaisan is not exposed southwards.

Line 235: "expected to be better preserved": what should be better preserved? And the European paleomargin represented the lower plate during the collision....
L 235: We rephrased this part of the discussion.

Lines 236 to 240: Ok, but which could be the reason? Please provide an interpretation
L 236 to 240: Yes this is due the high conductivity upwards. We have reformulated.

Tectonic reconstruction of Early Cretaceous rift in the SW Alps

Line 250: what do you mean with "differential extension"?
L 250: we removed "differential".

Line 251-251: What the expression "In case of westward propagation..." mean? Do you think a westward propagation occurred or not?
L 251: Yes, we modified for more clarity.

Line 254: "To the east of the Embrun...": better in the eastern part of the Embrun...
L 254: Modified as suggested.

Line 257: why "in contrast"? I would write: "...reflects the overthrusting of the E-U nappes bu also require heating..."
L 257: modified as suggested.

General comment: some problems and doubts remain concerning the reliability and accuracy of the applied RSCM geothermometer (e.g.. the drop not reproduced by models; the "colder" CAS section; very high temperatures in a non-metamorphic domain). I would thus be more cautious in proposing such extremely high geothermal gradients, and at least I would suggest that it would be necessary and interesting to apply other geothermometers (illite crystallinity index?) in order to confirm or not the presented T values.
We have developed this issue in the discussion. We do not believe that the RSCM data should be questioned because solutions exist to explain this gap although they have not been tested in our approach presented in this paper.

Line 272: "foreland deposition"? not clear, please expand and clarify
Done

Figure 1

- A) It lacks a legend. And in the external zone you should more clearly distinguish the Digne nappe
- B) The geological map of the external zone is hardly readable. It is too detailed, with a lot of not useful (and not homogenously distributed) elements that, given the figure size, make the figure itself hardly readable. In the caption please add that 15 original RSCM analysis are indicated, and report the name of the sampled stratigraphic sections. Delete the second "reconstructed".
- In the legend the symbols for the tectonic contacts are missing. And I would highlight the Digne main thrust with initials

Modified.

Figure 2

- The font size seems to me too small. Particularly the numbers in 2A and the text in 2C, almost unreadable. In 2B it is not specified that the values of the columns are temperatures

The figure has been modified to improve its readability.

Figure 3

This figure is too small, and the text and numbers. Almost unreadable. You could split the 6 diagrams in 3 + 3....

The figure has been modified as suggested.

Figure 4

The isotherms lines are too thin, difficult to see them

Modified as suggested.

Figure 5
Specify in the caption that the models are based on the two-rift hypothesis

Modified as suggested.