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Interactive comment on "Fault-controlled fluid circulation and diagenesis along basin bounding fault systems in rifts – insights from the East Greenland rift system" *by* Eric Salomon et al.

Anonymous Referee #2

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In this contribution, the authors study a major basin-bounding fault, the Dombjerg Fault (NE Greenland), which juxtaposes clastic rocks against a metamorphic basement, generating a strong contrast of porosity and permeability in the two fault blocks. This work follows the previous work of Kristensen et al (2016), who identified a 1 km-wide cemented area along the fault core. This study, apart from new petrographic data, provides new geochemical data, specifically elemental composition, clumped isotopes and a nice dataset of U-Pb dates. These data allow the authors to establish the evolution of this cementation zone including timing of cementation related to faulting, timing of veining, temperature conditions, fluid origin and the main fluid flow paths through time. This paper is of broad interest and certainly fits the topics published in the Solid Earth

journal and the special issue "Faults, fractures, and fluid flow in the shallow crust". The manuscript should be improved before acceptance for publication, with considering the points below.

My main concern is that although the proposed scenario is pleasant, the results section, especially regarding petrographic description and in consequence its relationship with geochemical data, is too brief to give an idea of the validity of the proposed interpretations. Find below a more detailed explanation about this point and other doubts and questions. I have enjoyed reviewing this manuscript so I hope these comments could help to improve the manuscript.

Results section

The description of cements should be highly improved and the use of terminology more accurate. Drusy calcite means pore-filling calcite crystals increasing in size toward the center, what do you mean with coarse calcite? Which is the difference with drusy calcite? Do you mean maybe blocky calcite? In any case, size and morphology of crystals should be given. What about the CL of these calcite cements? What is the colour, is it homogeneus or zoned? Tough they have different textures, are they the same cement or are there different cements? Are there differences in the CL for instance from near-fault areas to distal-fault areas? After calcite cements, you talk about feldspar overgrowths, feldspar dissolution, quartz overgrowth and quartz dissolution in both cemented and uncemented areas. The way it is now written this section is confusing. In my opinion, you should stablish the paragenetic sequence in cemented and uncemented areas and describe it properly, in order, and with all the information. All this information is very important to validate your data. For instance, the two younger ages obtained in calcite cements, are really a recrystallization process or a later cement filling the remaining porosity?

The same comments can be applied in the following section about veins. You need to characterize the different generations of veins. Can you quantify vein density? Increases towards the main fault? I guess yes. How is the calcite or dolomite filling these veins (size and crystal morphologies, texture, CL)? Veins have one or several cements? Are they petrographically similar or different to host rock cement? What about fracture shapes and lengths? How is the contact between the vein and the host rock? Is it abrupt or gradual? What is the behavior of your veins (opening? Shear?)? How many generations of veins are present? You talk about two generations near the basement, what about in more distal areas? Looking at figure 5, it seems that you have at least 3 different calcite cements in veins plus a dolomite cement.

In this sense of distinguishing calcite cement generations in both host rocks and veins, it is surprising to me that you have not done the basic stable isotope analysis with a δ18O-δ13C crossplot. If you do this, you have two populations one around -5‰in δ18O and δ13C values between -25 and -15‰(group A) and another around -11‰in δ18O and δ13C values between -15 and -10‰(group B), which in turn are different from the calcite vein of 50Ma, the vein in the transfer zone and the veins near the fault core. It is true that when you add ages it gets more complicated and in different samples one can see opposite trends from A to B of different ages. But this has to mean something. . .moments of major inputs of meteoric fluids at different times?

Regarding these two sections, figures 3, 4 and 5 are disordered in relation to the text. You call first 3c, then 3e, 4b, 4c, 4d,f , 3b, 5a,b and then 3a! It should be reorganized so figures are called in order.

Line 224: you interpret that sample TBK2cem is recrystallized. Recrystallization is an interpretation and should be discussed in the discussion section and not introduced in the results. However, I think you should describe well these samples (TBK2 and G9cem) to justify that they are not a second cement generation filling the remaining porosity and support recrystallization.

With regard to elemental composition, you cannot characterize all your veins in the hanging wall together, as you have different cement generations (i.e. G36 and G22

with different CL (fig.5) and different stable isotopy). Moreover, some of them have important CL zonations that are going to imply strong variations at least in Mn and Fe.

Discussion section

I agree with the authors that cementation started soon after the deposition of the sediments, I think that the dates of TBK1cem, G-38cem and G36cem indicate this. Also veining started at the end of the rift climax stage as denoted by G10v1. However, I still have concerns about the recrystallization fact (possibly because of the lack of a good description. I think you should describe better these two samples G-9cem and TBK2cem, also adding good pictures). Is it possible that cementation occurred at different times at different stratigraphic levels in a heterogeneous way? I mean, is it possible that the beds where sample G9cem or TBK2cem are, were cemented after the bed of G38cem for instance? Or that there are two cement generations? Could be this date of 115.5 Ma the wrong one? Or if there is a recrystallization, what is the cause of this patchy, local recrystallization?

When using U-Pb dating in fractures and veins, usually we don't know whether we are dating fracturing or fluid flow (I have had the same problem). You discuss this fact in a certain way when you say that maybe you have fracturing during the rift climax and then cementation during the postrift. However, I think that your reasoning is not good enough because you base that veining (fracturing+cementation) occurs during the postrift because you have one vein cemented in the synrift and then more veins should be cemented (it is highly probable that there are more veins during the synrift, it is a sampling bias). I think that the key point is the texture of veins. Veins with crack-seal texture are a clear evidence of opening and immediate cementation. You said you have some veins with this texture. Do you have dates of this texture in the postrift? In veins with just an opening mode is more complicated. I think it could be good to add a column in table 1 indicating the vein texture. Anyway, I think that here the key point to highlight with your data is that cementation started soon after deposition followed immediately by veining, which lasted during the postrift.

Line 341: your explanations only work if you maintain the same water composition too.

With regard to the source of calcium and CO2 for calcite precipitation (seawater vs Permian carbonates). Why you haven't done 87Sr/86Sr isotope analyses? It could be a good way to discern the source and the level of fluid-rock interaction.

δ13C values are really low, up to -23‰, in your host rock cements and veins indicating organic matter oxidation. Where is contained this organic matter? In the own Lindemans Bugt Fm or in units below? Any idea about TOC contents or HC presence in the area?

You base your hypothesis of diffusion on the similarity of the elemental geochemistry between veins and their respective host rocks. I have my doubts about this interpretation, don't you think that an easier explanation is that cement and veins are derived from the same type of fluids? I also think that you can extract more information of these data (i.e. redox conditions, fluid origin. . .).

Figure 11, in my opinion, needs some modifications to be more representative of your story. In A, you establish an in-fault circulation of surficial fluids and upward metamorphic fluids. The latter are sustained by your data and discussed in the text but what are the evidence for the surficial fluids? If any, it should be discussed also in the text. Minor graphical comment: As the picture is in 3D, you should maybe paint these metamorphic fluids along the fault plane (as you have done with your in-fault circulation). In B, the arrow for the upflow of metamorphic fluids should be removed, right? Your data and your discussion points towards the presence of seawater and a mixing of seawater and meteoric fluids that increases towards the fault. This entrance of meteoric fluids through the fault zone that diminishes towards the basin should be illustrated. The same for C. I think there should be another sketch before D to illustrate veining during the postrift with their respective fluid origin to complete your story.

Minor comments:

Line 85: mafic and ultramafic rocks (in plural)

Line 87: dolostones and limestones, or just carbonates, as you prefer but not a mixture

Line 90: rewrite description of Bernbjerg Fm, I guess it is marine heterolithic mudstone-sandstone turbidites.

Figure 2: in the legend it should appear the blue color in the upper left corner of the image as well as the grey color.

Line 141:it is strange that you talk about carbonate vein and calcite cement when what you have inside the vein it is also a cement. I think you should say carbonate vein if you wish and then interparticle calcite cement or host rock cement, or something similar to be more accurate.

Where did you performed the clumped isotope analysis?

Line 179: does the cementation zone go farther into the basin in coarse-grained beds as it seems to be represented in this way in your figure 11?

Line 180: alteration zone –> cementation zone, it is better if you use the same concept along the manuscript. Line 183: how is the matrix of these matrix-supported conglomerates? Why are they preferentially cemented?

Line 188: biogenic calcite clasts –> calcite/calcitic bioclasts. What type of bioclasts? Can you give some examples? Are they fragmented? What happens with bioclasts in uncemented areas?

Line 206: Specify that the vein in the transfer zone is developed in the basement

Line 233: specify that this basement vein is the one developed in the transfer zone.

Value for G9 cem is different in the text and in table 1.

Line 355: is it possible that the temperature is correct? Sample G34 is located in the transfer zone between two normal faults. These setting are preferential paths for upward migration of hydrothermal fluids.

Line 364: patters –>patterns

In section 5.3 and 5.4 add ‰or ‰at your values.

Line 455: solidified –>lithified

Table 3: young veins –> Hangingwall Eocene veins.

Table 3: are you sure that G34 has all the elements below the detection limit? It's surprising, I have never seen that before. . .Is it not a technical problem?

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