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Interactive comment on "Spatiotemporal history of fluid-fault interaction in the Hurricane fault zone, western USA" *by* Jace M. Koger and Dennis L. Newell

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Dear Authors,

I thoroughly enjoyed reading your manuscript, which provides a detailed geochemical and geochronological study into the fault-fluid interactions of an active terrane bounding fault. In general, the data is robust, well presented, in placed within the scientific literature. In particular, Sections 5.1 & 5.2 provide nice summaries of your results, their implications, and represents the standout part of the MS. It was also refreshing to see a clear presentation of the uncertainties behind the presented conceptual models. While I have a number of minor concerns regarding the contextualisation of the presented

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data, in particular how this relates to the structural relationships, this manuscript will be of great interest to the readership of Solid Earth. I therefore suggest the acceptance of the manuscript pending minor revisions. Please find my detailed comments and suggested text edits on the annotated PDF and a summary of my major and minor comments below. Kind regards, Billy J Andrews

Major comments

MC1: Lack of structural data and the field context of the samples.

A large omission from the manuscript is structural data from the different field sites and the structural relationship of the described features. This makes it difficult to place the geochemical analysis into a field setting. Wide-angle field photographs, and the inclusion of some of the field photographs in the supplementary information would greatly aid in this. I was surprised no fault or vein data was presented, either in the supplementary information or as a stereographic projection associated with the geological history of the fault. Your geochemical analysis is fantastic, but you quickly lose context without linking this to the observed structural relationships. You highlight, and I strongly agree, that the structural diagenesis, and in particular field relations and timing of these events is fundamental to the geochemical analysis. It is clear from your supplementary information, methodology section, and in part the results that this has been considered during fieldwork, However, when reading the manuscript I was often left to read between the lines, or search out images in the supplementary information, to work out what this looks like. Please consider further elaborating on the structural relationships and moving some field photographs from the supplementary information into the main text so the reader has context to the geochemical analysis.

MC2: Confusing age relationships & unclear fracture attributes (Section 4.1).

I found the vein and fracture data presented in section 4.1 rather confusing, something that was not aided by the already highlighted points in MC1. You make reference to fracture density on line 257, however, I found it very unclear how you calculated this

and whether it referred to P10 that is most often referred to as fracture intensity (f/m), or P20 that is more often referred to as fracture density. If this data was collected using scanline methods, what was the length/radius/area of the scanlines as this can have a very large impact on the reported values. If not how was the reported 'densities' calculated? This will be compounded by the fact you appear to have several fracture corridors, as suggested in line 226 where P10 will locally drastically increase.

Regarding the reported 'orientation sets' I have some the following specific questions: 1, How do the orientation sets relate to the age sets? i.e. are there systematic cross cutting relationships or are both orientations reactivated throughout the 4 stages derived from the geochemistry? 2. Where has the strike and dip data been derived from and why is strike so clustered when the fault trace at a map scale is so variable? Does the presented data represent the mean of a larger sample set and if so how many datapoints were collected? This would provide confidence that the heterogeneity of the system had been captured. Additionally, I don't understand how a dip can be 90 + 20 as the maximum dip is 90. I would like to see this data presented in the manuscript, potentially in stereonet form associated with the map? 3. I understand the more detailed field relationships were included in the supplementary information due to the focus of the paper, however, only the keenest readers will delve into this and you risk the context being lost to the majority of your readership. I suggest adding a paragraph to the main text that briefly summarises the supplementary information.

Line by line comments

Throughout the text: Please can you be consistent with the capitalisation and name of the fault. Within this paragraph is it referred to as "Hurricane fault-zone", "Hurricane Fault", and "Hurricane fault zone". Due to the segmentation I would suggest fault-zone is most appropriate. L8: I've always preferred 'fault-fluid' as the deformation is required to localise the fluid flow, with fluid impacting later deformation. L12: I've always preferred 'fault-fluid' as the deformation is required to localise the fluid flow, with fluid impacting later deformation. L16: How are these differentiated as there errors

overlap? L17: All the data is taken from the FW, if possible in the word limit I would be explicit in this sentence. L31: I fully agree but It may be worth citing a few of the seminal texts, or particular pertinent texts to this study, here to direct interest readers. L32-62: This paragraph provides an important regional context that is also really important for introducing the concepts developed in the MS. I would however suggest that you split the paragraph into two- either one for each case study or a paragraph to highlight the value of studying fault-systems with ongoing fluid flow due to the tight age restraints and well defined structural evolution. L35: With the basin-bounding nature of the Hurricane-fault I think it would be worth directing readers to work such as Johnathan Caine's work on the Dixie fault (cited in this MS) and some of the work coming out of Bergen from NW Greenland (e.g. the Pre-print in this SI -> Salomon, E., Rotevatn, A., Kristensen, T. B., Grundvåg, S.-A., Henstra, G. A., Meckler, A. N., Gerdes, A., and Albert, R.: Fault-controlled fluid circulation and diagenesis along basin bounding fault systems in rifts – insights from the East Greenland rift system, Solid Earth Discuss., https://doi.org/10.5194/se-2020-72, in review, 2020. And references therein L66: This sentence is incomplete/an amalgamate of two different sentences? L66-67: please include the lithologies and what is exposed in the HW and FW of the fault. L67: please be specific here, particularly for reader who are not familiar with the geology of W. USA L75-78: This reads more like and abstract and could be removed from the introduction. Instead I suggest that you signpost the specific research gap you hope to fill. Maybe something like "Our data enables us to constrain the source and $\sim$540 ky evolution of fluid flow and fault-fluid interactions within the footwall of the Hurricane Fault-zone." L146: How was the degree of representation assessed? I struggled a little with understanding the outcrops from the main text alone and feel the main text sorely misses the context of field photographs, of which there are some very nice ones in the supplementary information. I strongly suggest that some of these are moved into the main text, and potentially one or two wider angle photographs included to help with contextualising the presented data. With only 6 figures and nice short nature of the MS I see no issue with adding another Figure. L215: Also structural diagenesis

after Laubach et al., 2010 L218: best preserved or do you think it was localised within these competent lithologies? i.e. did diagenetic mechanical stratigraphy play a role in the fluid flow evolution of the fault zone? L217: How is damage zone and fault core constrained? I know this is not the main crucks of the paper, however, the distance that samples were taken from the fault core could impact the extracted data and overall interpretations (probably only minor in this case looking at the presented data). For reference on considering the thickness of fault zone and the bias can i suggest Shipton et al., 2019 doi: https://doi.org/10.1144/SP496-2018-161 L245: What about structural relationship? L246: Is there any visually difference between the sets? The geochemistry story is really well presented in this MS, however, I am struggling to link this in with the observed structural relationships. L256-257: What about uncertainty due to fluid degassing? L261: What does aperture refer to, short axis? You mention long axis in the previous sentence, how elongate are the fluid inclusions? L265: This depends on inclusion size, but in general i agree L279: Do you have a field photograph of this you could add to the supplementary or main text? L317: this is fairly low for saline fluids, could they be saline influenced meteoric fluids? L323: How appropriate is this for a terrane bounding setting that has had extensive volcanism? Do you have any constrains from well data? I would expect an elevated geothermal gradient. L392: One thing that may be worth signposting in the introduction is the high resolution of dates that can be obtained through the study of these systems (and hence why studies such as this are so important to the community) L441: I struggled to assess how robust this was from the presented data. The four geo-chemical set's is clear but how this fits into the field relationships is ambiguous. You only mention 2 'orientation-sets', how does cross cutting relate to these? L449: This is strongly suggested through your vein micro-structure you have presented both in the main text and the supplementary information.. this is a larger dataset and backs up the smaller dataset. I think it is worth highlighting this. L454: Is it feasible to have no exhumation of the footwall? I am not sure i agree, particularly with the differential elevation observed in Fig1. L456: see point about geothermal gradient in the previous section.. does this also have im-

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plications for the published estimates at Pah Tempe? L463: Mineralised breccias can also form due to rapid burial & differential fluid column height, see Peacock et al., 2019 -> https://doi.org/10.1111/ter.12371 L483: The shallow nature of this is a key point to highlight, although it will be a low estimate due to exhumation & erosion of the FW L491: This will have strongly effected the flow properties of the system. L523: What is the grey-scale range? could you add a scale for this in the top left of the image? F2: I would like to see the lithologies other than the basalts either in a stratigraphic column or in the presented map. Could a colour scale for elevation be added to the figure? F3: Generally really nice figure, however, a couple of suggested edits: 'calcite veins sets' appears to be slightly rotated? How are these slopes calculated? There appears to be a lot of scatter. What is the uncertainty in slopes? F4: (inset) It appears the frequency does not match the presented n values? Is there not 7 results presented for set 1 & 37 for Set 3. F5: The text size for the lithologies are too small

Supplementary information

FS1: (1) What are these two EW trending black lines referring to? The state boundary? (2) The text size for the segments are inconsistent (3) is the fault trace truly contentious? FS2: (1) Section boundary out of alignment with the figure below, i suggest shrinking the formation column slightly to give more space for the text in the member column, (2) At several points the variable text size impacts the readability of the figure. Additionally "THICKNESS" and "LITHOLOGY" should not be in full capitals. Being slightly unfamiliar with the local geology I'd have liked to the stratigraphic column in the main text to aid broader context. It could be combined with Figure 2? (3) The schematic log needs a key & grain size scale. (4) Capitalisation is missing for several Geological members (e.g. Upper Red Member) L13-14: This sentence is a little clunky, consider revising L14: Could you please present the kinematic data for the described structures either in the main text or supplementary information? How many sets and what type of sets (age, chemical, orientation)? L15: Please also check the fault name is consistent in the supplementary information and figures. L16: what proportion of the

samples/studied structures? L31: How continuous are the fault breccias? L36: what is the spatial distribution of these cemented breccias relative to the main fault? L39: It would be good to see the lineation data preserved on these. Is there any variability between layers? purely extensional or is there a dip-slip component? How variable is the kinematic data across the different sites? FS3: This figure is nice and provides some of the structural context that was missing in the main text. However, could the orientation of the field photographs please be included in the figure. For clarity a scale bar could be useful (or a mention of the length of your scales in the figure caption). Also the lettering needs to be aligned with each other. In (f) mineralisation appears to be tracing along pre-existing structures here. I think a clear differentiation between 'age' sets defined by geochronology and geochemistry and 'orientation sets' needs to be woven into the manuscript. FS4: Please align lettering and similar to the previous supplementary figure please add in a scale bar and orientation to the field photographs L48: What is the type of fault breccia? L54: Do you have an appreciation of the relative timing of this alteration? is it recent GW circulation or related to the mineralisation? Is it preferentially related to specific fracture sets and/or orientations?

Please also note the supplement to this comment:
https://se.copernicus.org/preprints/se-2020-69/se-2020-69-RC2-supplement.pdf

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