Referee Comment (RC) 3

We are grateful for the feedback provided by an anonymous referee (AR). The referee raises four (RC3 – 1 to RC3 – 4) main concerns, which are addressed in detail below. Furthermore, specific comments to individual points of the manuscript are provided in an annotated pdf. In the following, we will repeat the referee's statements (in bold font) and our reply to it. Below the responses to these main concerns, we respond to the specific comments on the manuscript except for cases where e.g. typos are highlighted.

RC3 – 1

The results section is sometimes hard to follow. My suggestion is to avoid wording, long sentences, the different classification of clast within the cataclasite (i.e. matrix clast, bright matrix clasts), the different sub-classification of cataclasite (i.e. hangingwall-proximal gouge, footwall-proximal gouge) and so on. I suggest to the author to shorten and simplify this part, maybe focusing on the striking differences between the different outcrops. In addition, within the description of the results there are several jumps from an outcrop to another. This confuses the reader. One solution can be to divide the results chapter with sub-sections based on the description of the different outcrops (i.e. sub-section 4.1 Havelock Creek, 4.2 Gaunt Creek, 4.3 Waikukupa Thrust, 4.4 Martyr River, 4.5 Borehole microstructures and so on). This will help the reader to have a better idea of the peculiar structures within the different locations.

In this paragraph, the reviewer expresses concerns regarding the style of the results section. Two aspects detail these concerns: (I) wording, long sentences and classifications introduced and (II) outcrop description being confuse as there are jumps from an outcrop to another.

With respect to aspect (I), we will aim to simplify our wording and shorten sentences in the revised version of the manuscript (examples where this has been suggested by the reviewer are very helpful). One aim of this paper is to provide a detailed characterization of Alpine Fault gouge with respect to microstructures, mineralogy and geochemistry. This requires a description of observations, which facilitates to compare observations made in different studies. For example, matrix clasts, though sometimes termed *reworked gouge clasts,* have been reported previously (see Boulton et al., 2012; Toy et al., 2015; Schuck et al., 2018). In this context and as described in the manuscript, bright matrix clasts are a distinct feature and *bright matrix clast* appeared to be a reasonable term to describe this feature. Similar reasoning applies regarding the terms *hanging-wall- and footwall-proximal gouge* (see also Schuck et al., 2018). These terms describe distinct features observed at two locations. Furthermore, as the formation of these features in discussed in the discussion section a proper labeling appeared necessary.

With respect to aspect (II) we disagree with the reviewer. To the end of characterizing the PSZ of the Alpine Fault, we report at the beginning of the subsections the main observations valid for all investigated locations (see e.g. lines 245 – 259 or lines 357 – 362) before presenting observations specific for one or some of the locations (e.g. lines 319 –

323); hence the structure of the sections is guided by individual observations. The suggested re-arrangement to base subsections on the description of the different outcrops has been tried in an earlier version of the manuscript. However, the description of microstructures, mineralogy and geochemistry was repetitive, which unnecessarily extend the results section. The chosen structure of the manuscript provides (a) a holistic description of Alpine Fault gouge and (b) shows differences between individual locations.

RC3 – 2

In addition, I suggest also to split the two figure of microstructures in three, in order to do figure with larger panels. In this way can be easier to see the detail of microstructures. Please, enlarge also Fig. 4 and 5 (two column wide).

Figures 2 – 7 and 9 are designed to be two columns wide. Their smaller width in the submitted manuscript originates from the template used. We hope that it will be possible to display these figures two-column-wide, if this manuscript will be published.

RC3 – 3

I suggest to draw a conclusive general sketch where the main microstructures are highlighted regarding to the different locations. For instance, a similar (but a lit of bit more detailed) sketch as that of Fig. 10, also with the other outcrops, and a map with arrows indicating the different positions of microstructures. In this case the reader will have a complete picture of the different microstructures according to position along the fault.

Figure 9 of Schuck et al. (2018) provides a conclusive general sketch highlighting the main microstructures. Microstructural differences between individual locations appear to be minor, hence it appears elusive to sketch these subtle differences. Nonetheless, we will consider including such a sketch in the revised manuscript once all referee comments will have been included in the manuscript.

RC3 – 4

Line 525-530. Seismological investigations showed that during a fault rupture the slip distribution along a fault plane is always heterogeneous, with zones characterized by high displacements and zones characterized by low to zero displacements, both at surface and at depth (e.g. Ma et al., 1999; Lin et al. 2001; Tinti et al., 2016). This can affect the production and the thickness of fault gouges and the distribution of fault rocks. The observed differences in gouge thickness could be explained also by different displacements occurred along the same fault plane, rather than the product of multiple displacements along several fault strands? Are there evidence of multiple fault strands at the surface or the area is too vegetated to map such complexity?

In this comment, the referee addresses two aspects: (I) potentially differing amounts of displacement accommodated and (II) the presence / absence of multiple faults strands and the dense vegetation obscuring their identification, respectively.

Regarding aspect (I), locations *DFDP-1 / Gaunt Creek*, *Havelock Creek* and *Waikukupa Thrust* are situated in the central segment of the Alpine Fault, location *Martyr River* is located in the fault's southern segment (see Figure 2 of the manuscript). While it is known that the fault might rupture along its entire length, differing recurrence intervals for the central and southern segments suggest that individual fault sections might fail independently of each other (see also section 2.1 of the manuscript). However, the entire central segment is considered to rupture in case of an earthquake (see lines 524 – 526; Sutherland et al., 2007; Howarth et al., 2018). If one assumes that there is only one fault plane, earthquakes rupturing the entire central segment suggest that PSZs investigated in the central segment have accommodated the same displacement. However, in this case PSZ thicknesses should be more similar than they actually are.

Regarding aspect (II), the area is indeed densely vegetated, which is the reason for the sparsity of locations providing access to the PSZ. However, in two different settings there have been indicators of / direct evidence for more than one fault strand. (a) DFDP-1B is the only location of the central segment of the Alpine Fault, where there are two PSZs (see Figure 3a in the manuscript). Both PSZs are bound by fault rocks. However, the presence of these two PSZs has so far not been discussed in the context of fault zone architecture. At locations where both hanging- and footwall are covered by tens to hundreds of meter thick Quaternary sediments, shallow imaging techniques detected multiple fault strands (Kaiser et al., 2009; Carpentier et al., 2012) and there are indications that at least some of them might extend into the basement (see also lines 546 – 548; Lay et al., 2016; Lukács et al., 2018).

These aspects (two PSZs encountered in DFDP-1B and multiple fault strands detected by shallow imaging techniques) is also discussed in the reply to referee comment 1 and will be elaborated in more detail in the revised version of the manuscript.

Below we respond to the specific comments that were made as annotations on the manuscript. Numbers refer to the line in the original pdf where the reviewer placed his comment

l. 54:

AR*:* Please, synthesize from line 30 to 54.):

Our response: Lines 31 – 54 review fault zone architecture and the two end-member models of fault-zone architecture presented by Caine et al. (1996) and Faulkner et al. (2003), respectively. These provide a fundamental framework for the discussion of our observations and we would like to retain them.

l. 65: The fault is dominantly transpressive and runs through the South Island of New Zealand.

AR: dextral or sinistral?

Our response: We will modify this to "dominantly dextral transpressive"

l. 238:

AR: please insert coordinates in the caption of Fig. 2.
Our response: We will do this as requested.

l. 254/255:
AR: I suggest to avoid the term “matrix clast”, maybe is better only to use the term “clast”
Our response: The term *clast* is not unambiguous. A clast could also be a larger quartz grain embedded in the matrix. We prefer to retain the qualifying “matrix” to make it clear what there features are.

l. 313: Many of these fractures contain up to 305 µm wide calcite cores, locally surrounded by gouge, microstructurally similar to microfaults observed within the DFDP-1A cataclasites
AR: Cores” – you mean crystals? […] Figure of this microstructure.
Our response: We really do mean core. The corresponding figure is Figure 6i (reference in line 314).

l. 404: Slickolite
AR: stylolite?
Our response: As detailed in line 317 a slickolite is a special form of a stylolite, and this term describes the observed feature more appropriately than the more generic term *stylolite*.

l. 440: section 5.2.1
AR: all this is not a discussion of the results presented in this paper. This should be deleted or moved in the geological setting above
Our response: We reviewed the different views about the extent of the Alpine Fault’s brittle part (namely its damage zone and its fault core) presented in previous publications in section 5.2.1 and the first part of section 5.2.2, and then discussed how our results inform a better understanding of the Alpine Fault’s architecture in the rest of section 5.2.2. If we move section 5.2.1 to the *geological setting* section (as suggested by the reviewer), we would also have to move the first part of section 5.2.2 there, and then our new findings would be entirely without context so we prefer to keep it here.

l. 476:
AR: I imagine that this part is from your work. So I don't understand the relationship with the previous sentence regarding the faults in the death Valley
Our response: As discussed in our response to referee comment 1, we acknowledge that this paragraph (lines 471 – 476) and the succeeding one (lines 477 – 485) are misleading and will revise them.

l. 513: This suggests that strain localization within the fault core might be governed by processes insensitive of rheological variations caused by differing fault rock composition.
AR: Maybe related to greater fluid circulation a authigenic clay precipitation into narrow PSZ?
Our response: Please refer to our reply to referee comment 1 on this line.

Figure 2: Inserting a simplified section trace in Figure 2b is not possible, because (I) Figure 2c is a conceptual (composite) sketch depicting a shallow-depth transect across the Alpine Fault and (II) the scales of Figures 2b and c differ so much that the section trace would be too small to be recognized in Figure 2b. We will indicate the DFDP-2 borehole with a different symbol.

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