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Interactive comment on "Structure of massively dilatant faults in Iceland: lessons learned from high resolution UAV data" *by* Christopher Weismüller et al.

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Reply to 'Comments' by Anonymous Referee #1:

Anonymous Referee #1 Received and published: 30 July 2019

In the present paper, the authors studied the surficial expression of some normal faults in Iceland, mainly using UAV-derived digital surface models and orthomosaics. They classified them, based on the surficial expression, as well as they collected several quantitative measurements and provided dilation and vertical offset profiles; they also related vertical offset and horizontal dilation with the aid of field checks, to provide

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Discussion paper

new findings on the above-cited topic. I generally appreciate this kind of study where plenty of data are provided and that present new approaches and technologies, and I recommend the paper for publication, but only after a major review with the aim of improving the structure of the manuscript, data presentation and to better highlight the results.

Reply: We thank Reviewer #1 for the comments on the manuscript. A main criticism was that the objective was not clearly stated, and some restructuring of the manuscript was in order. In the new version of the manuscript we have taken special care to clarify the scope of the study, and restructured the manuscript particularly in section 1, as requested. Suggestions to merge parts of the results and interpretation were not accommodated, but we consider this mostly a matter of taste how to lay out the manuscript. Detailed comments on the individual points raised by the reviewer are provided below.

Introduction and discussion The introduction must be improved addressing in clear manner the methodology or the scientific problem presented in the paper. In the present form, there is a large list of cited literature but the subject of the paper is a bit vague. It is not clear if that is a test of a new methodology to study normal faults (e.g. UAV survey without GCPs) or if the aim is to present new findings on fault classification at the surface. Up to now, it looks somewhere in the middle.

Reply: We have used a, to our requirements modified, version of a recent, but well established technique to create digital elevation models (DEM) from unmanned aerial vehicle (UAV) photographs. Based on these data, we developed a workflow to extract large amounts of measurements in high resolution, which enabled us to introduce a new classification scheme for the faults at the surface in combination with our field observations. Therefore, the manuscript indeed deals with both aspects: The UAV-DEM are the methodology we used to acquire the base for our geometrical analysis of the faults and fractures, which is the main aspect of the manuscript. To clarify this, we modified the final paragraph of the introduction to make the goal of the paper, using high-res

UAV data over kilometer scale faults to improve the surface fault classification beyond simple geometric observations. We agree with the reviewer that this modification will make the scope of the study clearer to the reader.

In addition, the discussion must be better addressed; the core of the paper is unclear in this chapter and it is difficult to appreciate the value of the new data and consequent results. I strongly recommend reorganizing this section after the introduction has been improved and thus the focus of the paper has been clarified. In the present form, it is hard to understand where the new findings are, regarding both the method and the scientific problem.

Reply: Our discussing starts with a short recap of our methods and the therewith achieved resolutions, before we put our methods in respect to the literature. We subsequently introduce the parameter R, which will be used to further discuss our measurements and findings in the rest of the discussion. In the following section, we analyze distinctive features in our models and measurements to verify the applicability and special cases of our classification. This is done by first analyzing these features in the single models that have been introduced, before we include further data from ourselves and literature for a more general discussion. In that part, we test and describe our classification scheme more universally, leading to the conclusion that the different endmembers are part of a larger continuum. We are convinced, that this organization is a proper way to discuss our large amount of data in respect to the findings from our measurements, as the sections are not interchangeable but build up on the discussions in the preceding section. Therefore, we decided not to restructure the discussion. However, we hope that with the changes in the introduction and restructuring in the data presentation the scope of the paper as well as what are new findings is now clear.

Part of the scientific core of the paper seems to be presented in Section 1.2 that now belongs to the geological background. Geological background Sections 1.1 and 1.3 can be merged; they both describe the studied areas.

Reply: Section 1.2 introduces the reader in the topic of massively dilatant faults (MDF) and provides a summary of existing literature dealing with the formation and geometry of MDF, before the last lines put this manuscript in perspective to existing literature. This belongs rather in the introduction part and is not supposed to be the scientific core of this paper, as we are only dealing with one aspect out of the large variety of aspects of MDF described in this section. Section 1.1 is a broad introduction to the regional setting, while section 1.3 deals with the setting of our study areas in detail. We agree that these section can be merged. To highlight and underline the introductory character of the MDF section (1.2) we decided to move it up as new section 1.1, followed by a new section 1.2 which consists of the merged sections dealing with the regional and detailed settings of our study areas.

Methods 2.2 Authors applied the areal Structure from Motion technique using a “border line” level of frontal and side overlap, without GCPs. This has surely affected the quality and the accuracy of the model, and must be discussed more in the paper, please do quantify the error.

Reply: The general assumption that we used a “border line” overlap for our model is not correct. The values referred to represent the minimum values we worked with, mostly in the distant regions of our models. The important areas including the mapped fractures have been covered with higher overlaps. We have made this clearer now in the text. The impact of not using GCP in our data and how we dealt with this circumstance, also in terms of quality check, is already explained later in the methods (e.g, p.6 line 8 ff.), also with an error estimation derived from the onboard GPS accuracy, and additionally in the “ground truthing and field observations” section. We would like to point out, that this manuscript does not aim to be a methodological paper about UAV-Sfm and DEM generation, as we have just slightly adjusted an established methodology.

It also seems that the authors have not added any scale to the model/dense cloud.

Reply: We did use the UAV onboard GPS, which serves as scale during the processing.

Using the software (Agisoft Photoscan), it is not possible to create and export a DEM without scale or reference of the image-chunk. Quality checking of the model scale has been briefly explained in the ground truthing section. We have moved the paragraph to section 2.2.

In addition, referencing them with lower resolution dataset could have also introduced errors.

Reply: We did not reference our models with a lower resolution dataset, nor do we state doing so. We used the lower resolution TanDEM-X data to compare our models to in order to quality check with regional morphology, e.g. to identify local slopes of the surface. By doing so, we were able to rule out an artificial tilt of our models, which is a possible artifact when no GCP's are used. This is described in e.g. section 2.1.

Results Sections 3 and 4 can be merged since in both of them results are presented.

Reply: Section 3 shows pure results which are addressed as objectively as possible. Section 4 is the interpretation of the results shown in 3 and the structures are already classified as different endmembers/fracture types, according to our interpretation of the situation. Thus, while both being similar, section 3 aims to objectively represent the data, while section 4 is our subjective interpretation. Therefore, we would like to keep these sections separate to draw a clear line for the reader between results and interpretation.

Conclusions This section must be better addressed in order to highlight new findings, after that the introduction and discussion sections have been both improved, as suggested above.

Reply: We restructured the conclusions to clearer separate new observations and the most important conclusions.

Figures At a general level, the number of figures is too high. Some of them must be merged, especially when they are presenting the same type of data.

Reply: One of the fundamentals of this manuscript is to present and introduce the reader to our high-resolution dataset from a comprehensive study. Therefore, we deem the number of figures as necessary to provide the reader with a sufficient amount of information to make our interpretation and argumentations as transparent and reproducible as possible for the audience. To avoid repetitions and things of minor importance in the manuscript itself, an addition supplement with further data is already provided. We decline the suggestion to merge further figures, as we deem the perceptibility of details in our figures, when dealing with high resolution data, as one very important aspect. Merging the figures would decrease the resolution and therefore undermine this concept, especially when the figures are viewed in paper form and not on a screen that allows zooming in and out. We thereby merged already as many figures as possible and kept the figure count as low as we could, without affecting the quality of our data presentation.

1. The caption can be shortened, eventually adding details in the figure.

Reply: We agree. The caption of Fig. 1 has been shortened in favor of more details added in the figure itself, namely the hummocks, hanging wall and footwall, lava flows and possible fillings of the faults.

2. North and scale are missing. Change the symbol for surveyed faults; star is often used to indicate earthquake epicenters.

Reply: While we initially determined the existing coordinate system as sufficient, we agree that North and a scale make the figure easier and faster to understand. North and a scale have been added in each subfigure. To avoid confusion with epicenters, we have replaced the stars with rhombs.

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