

RC1: '[Comment on egusphere-2024-852](#)', Roy H. Gabrielsen, 11 Apr 2024

Summary and conclusions

This is an interesting contribution to the study of mechanically composite strike-slip systems as commonly found in nature, and as such, is relevant to the readers of Solid Earth. I, however, question whether the title of the paper fully reflects this complexity (see specific comment below).

The architecture of the paper is logical and appropriate. The experiments are well constructed and are well performed and reasonably well documented, although a keen reader may like to see some photography and blow-ups of some details (that should be selected by the authors).

The paper still needs substantial improvements on several crucial points:

- In the Description and Discussion only the effects of horizontally distributed mechanical contrasts are focused upon. This selection may be appropriate because these are the effects that are studied, but the influence of the vertical stratification should at least be mentioned and evaluated, not least because structures (faults) may be expected to nucleate at different levels resulting a hybrid thin-skin/thick-skin system. The authors need to explain why this selection was done, alternatively why the vertical stratification is neglectable. **It is my view that this is a methodological basal point that must be mended.**

We have improved the description of the setup, and also that the viscous layer overlying the plexiglass bars serves to distribute the applied simple shear deformation over the entire width of the model into the overlying brittle layer. Thus, our experiments focus on the role of upper crustal, brittle strength contrasts on strike-slip faulting.

- I have a feeling that the descriptions should be expanded fully to realize the full potential of the experiments. This view is supported by that the authors include some additional observations in the Discussion that were not included in the Description/Result-chapter.

We have rewritten the description sections, and improved the illustrations.

- The description of the faults in the Iberian Massif should be moved forward of the Discussion and the analogue value of the experiments should be demonstrated more clearly.

In the rewritten discussion chapter, we first discuss the analogue model results, and at the end – in section 4.4 – we then make a comparison between model results and a crustal-scale example in Iberia. We believe

that discussing the crustal faults earlier, would distract from the experimental results, which form the central focus of this manuscript.

- The Discussion chapter is the weakest part of the paper. It fails in displaying to the reader what are the new discoveries obtained by these experiments and to discuss this in light of current knowledge and literature in any depth. Also the observations that are comparable to that of the experiments should be included and discussed her. **I therefore recommend that a complete rewriting of the Discussion-chapter is demanded before acceptance of the paper.**

We have completely rewritten the discussion (see Reviewer 2 for main changes)

- Although presented in a logical sequence many phrasings and statements are unnecessarily complex, less precise and even ambiguous. I have made some suggestions for improvements below, but I suggest that the authors seek the advice of a person whose first language is English (mine is not).

Please note that no technical/formal aspects of the references (format, references, Solid Earth format standards etc.), nor the consistency between references given in the main text and the reference list have been checked by me.

Conclusion: This is a work that would be of interest to the readers of Solid Earth and deserves publication. At present, the manuscript, however, has several profound weaknesses that need to be mended before publication.

Specific comments

Title of paper

The experiments were constructed with both vertical and horizontal mechanical stratification and structuring. Thus, is not fully reflected in the title of the paper, and I would suggest that the authors consider whether or not an expansion of the title would be beneficial.

We have modified the title, which is now: "Strike-slip faulting affecting vertical domains of contrasting brittle strength in the upper crust: Insights from analogue models".

Abstract

The format and content of the abstract is good in that it defines the problem, displays the methods and emphasize the findings/conclusions. It can still be improved on certain points:

Lines 14-15: Perhaps the sentence "Understanding how strike-slip ..." should be moved up-front? Furthermore, the defined problem is generic and should be defined as such before mentioning consequences in applied science.

Lines 16ff: Suggest an expansion of this paragraph to avoid telegram style in the abstract, e.g.: "three experiment series were performed. The first experiment series utilized..... The second series of experiments, whereas the third"

Furthermore: I understand from the Methods-section that four experimental series (A;B:C and D) were performed? (although two were reference models)

I think the phrase "vertical contrast" should be specified to include "mechanical strength" or "rheological" throughout the remainder of the abstract. Perhaps this could be specified (e.g. "weak-strong", "strong-weak", strong-weak-strong")

It is acknowledged that the authors display clearly in the abstract where conclusions are given ("Our study shows that....."). Perhaps this important part of the abstract should be emphasized even more strongly, e.g. by introducing a new paragraph?

Line 19ff: Care should be taken so that the conclusions gave a consequent grammatical time sense in distinguishing between what was observed in the experiments and what is generally valid for such systems (see comments below).

We appreciate the feedback provided on the abstract as it improves this section of the article. Following the advice, we have made changes in the abstract incorporating the modifications that have been made to the article. In addition, following the reviewer's suggestion, we have separated the main results of the text into bullet points.

Introduction

Lines 54-55: Although involving time-dependent shear-configurations, Gabrielsen et al. (2023) touched upon on this problem in the analogue study of the Barents Shear Margin (Gabrielsen,R.H., Gianennas,P.A., A. Sokoutis,D.,Ernst Willingshofer,E.,Hassaan,M.&Faleide,J.I., 2023: Analogue experiments on releasing and restraining bends and their application to the study of the Barents Shear Margin, *Solid Earth*, 14, 961–983, 2023, <https://doi.org/10.5194/se-14-961-2023>).

We have now included this reference

Line 57: “behavior through changes....”, but perhaps better: “Rheological properties of the upper crust is of particular importance for the dynamics and geometry in strike-slip fault systems.”

We have partially rewritten the introduction (including line 57) and this sentence has been integrated in a modified form.

Line 63: Rather: The results from the experiments were compared ...”

We have rephrased the sentence.

Methods

The Methods-chapter is well designed and complete, but contains some formulations that could be improved/clarified:

Line 69: Is “utilized” better than “comprises” here? (It should be grammatical past, since the experiments definitely are finalized). Some of my colleagues with English as their first language (mine is not) would say this is a matter of taste, whereas others would disagree with this distinction.

We have rephrased the sentence (line 69) and now use past tense

Line 71: Rather: 60 independent and moveable plexiglass bars ... were positioned above the two basal plates”

We have rephrased the sentence.

Line 88: “.... consist of reactivated lithological boundaries”. Actually they represent contact surfaces of materials of contrasting mechanical strength. Do you mean “were analogues to lithological boundaries” (as actually stated in the chapter on Analogue Materials)? Please state the relative strength between the quartz sand and the (glass?) microbeads already at this stage (perhaps referring to the Analogue Materials-chapter).

We have changed this according to the suggestion of the reviewer, and now use vertical domain boundaries of contrasting brittle strength, and we have added possible natural analogues, such as terrane boundaries or rock units of contrasting strength separated by vertical boundaries (e.g. a magmatic body with steep margins that intruded into a sedimentary sequence)

We prefer to introduce the analogue materials in a separate section (2.2).

Line 90: Can the N-direction be indicated in Figure 1 for clarity? This means that displacement was oriented transverse to N in series A (i.e. E-W). For the continuation, I would suggest: "Three model sets with the quartz layer oriented with contrasting orientation relative to N were tested, namely.....".

We have added a N-direction in Figure 2.

We have improved the description, so that it is clear that we both change the orientation of the vertical domain boundaries and that we have a central domain, which consists of a brittle material that has a contrasting mechanical strength compared to the domains on either side.

Line 102: Suggest reformulation: "Pictures were taken by fixed intervals of 30 secs for the experimental run of 120 minutes, totalling 240 pictures for each experiment".

Line 104: Suggestion: "This software **allows for** camera calibration" (please say which parameters were calibrated for: only camera functions like exposure time etc or something else?). It also supports image correlation and".

Lines 107-108: Suggestion: "Each picture covered....". Why is the pixel coverage average? Did it vary from exposure to exposure, or is this an effect of changing perspective? Please say. Also: X and Y axes" are plural, so rather X-axis and Y-axis. Again, why is resolution an average value?

Regarding the three comments above: we have now a separate section (2.4) in which we describe in detail the deformation monitoring and quantification. In fact, we also corrected the above statement, as pictures were taken every 60 seconds (and not every 30 seconds).

Line 112: Should it say "neutral" or "parallel "strike-slip set-up (to make it clear that no transpression or transtension was involved)?

In our opinion, simple shear is precise as it is; the set-up simulates simple shear (see model set-up and Figure 1)

Lines 112-113: The band of contrasting mechanical properties is an oriented at a high angle to the main strain vector in several experiments. This is likely to cause vertical displacement. Please comment in text on Methods.

In one particular model set-up (Model D2), we do in fact have oblique-slip reverse faults, which we describe and illustrate. We prefer to discuss this in the Results (section 3) and Discussion (section).

Analogue materials and Scaling

These sections are complete and well written.

Thanks, but nevertheless we made some improvements in the text and in the tables (as requested by the other reviewers).

Lines 142-143 Suggestion: “**was** sieved” etc. See comment to line 69.

We have changed to past tense

Results

I think a short text here reminding the reader about the difference/similarities between the three (four?) series would be in place here.

We have added a short introduction in the results section

There is some confusion when the description of the different segments are concerned, shifting between (eastern, central and western) domain, zone, band, contrast. I suggest that domain is used consequently as actually spelled out in lines 89-93.

We agree that the terms used may be confusing, so we have tried to be consistent with the terminology, and now use consistently “domain” and “vertical domain boundaries”

Series A

I would suggest a slightly different introduction here, e.g.: "Series A1 and A2 were conducted to investigate the effects of the use of pure quartz sand (serie A1 and microbeads A2). As expected these experiment series were rather similar, but incremental strain panels for the quartz sand showed, whereas similar imagery for the microbeads..... "

Lines 171 ff: see comment to line 69.

Lines 185-187: There seems to be a confusion between the major text, Figure 3 itself and the figure caption here.

We have rewritten the results of Series A.

Series B

Line 189: Should rather read something like: " has a 5cm wide central segment with contrasting mechanical strength (microbeads embedded in quartz sans (B1) or quartz sand embedded in microbeads (B2). This band of mechanical strength divides the model into an eastern and a western segment"

Lines 170-200: These sequences contain some not clear phrasings/less good language and also contains some dubious statements. It should be rewritten. Examples:

Lines 196ff: Deformation cannot be compartmentalized, but strain can be distributed among several fault compartments.

We agree and have reformulated. We have also changed the order in which we describe the models with vertical brittle strength contrasts, so that the order of description in both "Results" and "Discussion" section is more logical. We now start both results and discussion section with N20°E vertical domains, followed by N-S vertical domains and finally with N20°W vertical domains. We have also improved the figures, as suggested by one of the reviewers, by adding background photographs of the different time steps, and by overlying a top view photograph of the final deformation stage with a line drawing of the interpreted finite fault pattern.

Line 193-194ff: Since this is a primary contact, I would say “activation” rather than “reactivation”.

Line 193: I think this phrasing is the correct description of this boundary: “In both models, initial simple shear results in **re**activation of the N-S rheological boundaries” (though there is a superfluous comma, and since this boundary was induced in the model construction, it was activated and not reactivated).

A good point, we now use “activation” instead of “reactivation”

Lines 194ff: Synthetic and antithetic are relative terms. These faults must be syn- or antithetic relative to something. Say what. And if they did not exist as faults on beforehand, they are activated, not reactivated. There are two sets of structures that potentially can be/are sources for strain concentration and contrasts in deformational style here. These have transverse orientations: One is defined by the basement (sinistral) shear fault and the other is the rheologic contrasts affiliated with the central segment, and they are located at different levels in the experiment. One should expect structures related to these structures to be nucleated at different levels and to develop (primary) thick-skin and thin-skin structures respectively. These tentatively belong to separate stress (depth-dependent) regimes. Again: for the surface structures: syn-/antithetic relative to what?

As mentioned in the “Methods” section, our model set-up is such that the movement of the mobile base plate changes the configuration of the overlying assemblage of 60 individual and moveable plexiglass plates from a rectangle into a parallelogram, simulating simple shear. The presence of a viscous layer overlying the plexiglass bars ensures that the basal simple shear deformation is transferred to the overlying brittle layer over the entire width of the model. We have also improved Figure 1, to better illustrate the model setup (including the vertical domains in the upper, brittle layer).

We now indicate that the sinistral strike-slip faults are synthetic faults with respect to the bulk sinistral simple shear, and that the dextral strike-slip faults are antithetic faults.

General for this section: Many authors use the terms syn- and antithetic structures for R-, R'- and P-structures. Considering the set-up here, I assume the authors mean something else with the nomenclature applied here. Please comment and explain.

In our experiments we refer to sinistral faults as synthetic and dextral faults as antithetic faults, to indicate their orientation relative to the sinistral shear stress applied.

Lines 200-211: This is a complex and unclear phrasing. Please consider something like: "Both in Model B1 and in Model B2 dominant fault strike for the dextral faults are different when the western and eastern domains are compared, striking and respectively. The new faults have an inclination of ... degs with the border between the quartz sand and the microbeads." Hereafter: Specify structure and dynamics and for each domain (referring to the rose diagrams in Figure 4) for one domain at a time and high-light the most significant observations. Please avoid over-qualification of statements like: "dextral strike-slip faults". All faults with dextral displacement are strike-slip faults in this setting.

We have rewritten and improved the description of the Series B models, and are now clearer in the description of the fault strike.

Series C and D

Lines 221-265: Please straighten description of series C and D in accordance with series A and B.

Also these section on Series C and D contain some unclear statements, for example "There are more sinistral faults in model C2 than in model C1 (Fig. 5c and h), and both cut the central band." (both what??) I guess you mean: The central **domain** is transected by the sinistral fault set in both cases".

"...change its strike counterclockwise in the central **domain**" Why not: "The faults in the central domain deviate by xxx degs (counterclockwise) as compared to". Actually, this is actually precisely phrased for the C-series in lines 227-229.

We have rewritten the description of Series C and D.

Discussion

The discussion is not mature for publication: It has the flare of a continued description, and several points and statements should be transferred to the Results chapter.

I see of course the point on the removal of the cardboard sheets, but cannot see that this is appropriate for the intro to the discussion. Furthermore, I would hardly call this a reactivation, which is consequently stated in this paper (see comments to the text). The border was perhaps slightly disturbed, but it hardly affects the *de facto* function of this surface as a primary zone of mechanical strength contrast.

This part should rather be transferred to the experimental set-up section.

We appreciate the feedback on the discussion as it has allowed us to improve it. As mentioned in the comments below as well as in the manuscript with the tracked changes, the discussion has been substantially modified including new sections and figures.

We have removed the cardboard sheets removal from the discussion; it is now included in the Methods section (section 2)

Introductory remarks to Discussion

I do endorse a general introduction to the Discussion chapter, but I think the introduction rather should be used to high-light the generic (experimental and geological) problems that are addressed in this paper, stressing the original aspects of these experiments and mentioning in which geological context(s) the results will be useful. Perhaps some elements from the Introduction of the paper should be repeated or moved here.

We appreciate the reviewer's suggestion as allow us to improve the discussion section, and we agree. Accordingly, and following the comments of reviewer 1 as well as the other two reviewers, we have rewritten the discussion.

The main body of the Discussion

After mentioning the generic problems raised before and materialized by the current experiments, these should be addressed one by one and *discussed* in light of previous knowledge by the authors (the second author is a world-leading scholar on strike-slip faults) and published literature. The items addressed in chapters 4.1 and 4.2 could be singled out as generic problems in this context and incorporated here.

In this context, field observations would be crucial, and I find it strange that data from the Iberian Massif are presented *after* the Discussion (see comment below). Rather, these observations should be part of the Discussion. I recommend a full re-writing of the Discussion chapter, and have therefor not commented upon this in detail. (But there are many statements in the thant would need a brush-up).

We have completely rewritten the discussion as suggested by both Reviewer 1 and 2. We now systematically discuss the four series A-D, starting with Series A (section 4.1), and then (in section 4.2) we successively discuss the three series of models with vertical domains of contrasting brittle strength, taken into account previous published literature.

Concerning the commentary on the field observation, we have stuck to presenting the results on a cartographic scale. In outcrop observations, this can be more difficult to observe, so we have restricted ourselves to the cartographic scale.

Figures

The figures in this paper are well taken and well presented, but it seems that more attention should be given to Figure 2, its general description in the main text and its Figure caption. The figures do, however, contain some details that easily can be lost if the present lay-out/size is maintained in the final publication.

I suspect that an additional figure would benefit the Discussion chapter if this is rewritten to include what is suggested by me above. The present Figure 7 is more a summary figure than a figure that would high-light a more profound discussion.

Note that we have improved all figures and have made sure that their style is uniform. We have changed the order and numbering of figures 4, 5 and 6. Figure 4 now describes the N20°E vertical domains, Fig. 5 the N-S vertical domains, and Fig. 6 the N20°W vertical domains. We have added a Fig. 7 to discuss and illustrate the difference in fault strike between the two Series A Models. As suggested by the reviewer, we have now included a schematic figure (Fig. 8) summarizing the main fault patterns of the models with vertical domains of contrasting brittle strength, to facilitate their discussion in section 4.2. A new Fig. 9 is used to discuss and illustrate in detail (section 4.3) how faults interact and/or link in selected models. Finally, the discussion of the comparison between the experiments and a crustal scale strike-slip fault system in Iberia has been improved (now section 4.4) and is illustrated by Fig. 10.

References

References have not been checked by me other than in the cases I had to look up references given in the main text.

We have removed checked the references in the text.