Response to Revisions

Dear Editor van Dinther, Dr. Bauville and Dr. Rosenau,

Thank you for these careful revisions. We have made several changes following your constructive comments. The most significant of these changes includes a new supplementary figure (Fig. S5) that shows how frictional work changes when we assume varying ratios of principal stresses (in which the tectonic normal compression exceeds the lithostatic), and how internal work changes when we use different elastic moduli to convert strains to stresses.

We respond to individual comments point-by-point below with bolded text. We number our responses for clarity.

Sincerely,
Jessica McBeck

Comments from Referee:

A. Bauville (Referee)

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General comments:

This article presents a set of laboratory compressive sandbox experiments in association with a detailed analysis and discussion of the mechanical work of the sand pack. During the experiment, the authors monitored forces on the back wall using pressure plates and particle displacement on the side using digital image correlation (DIC). The paper is innovative from the technical point of view. Indeed, using back wall force measurements and DIC, and calling on mechanically motivated assumptions, the authors managed to estimate individual components of the mechanical work in a laboratory experiment. The conclusions confirm the theoretical predictions that were developed in previous publications by the authors. The paper is well organized, the language is good, and the figures are clear. Figures representing graphs are well used (Fig. 3, 4, 8) and are useful to the discussion. Some of the figures showing the experiment and DIC analysis are used more anecdotally (Fig. 2, 5). The literature review is mainly focused on the previous work of the authors and could benefit from being a bit broader, especially regarding older works. In conclusion, this paper is an interesting contribution to the mechanical work of compressive tectonic systems. The focus of the paper is adapted to the journal Solid Earth. I support the publication of this manuscript after some minor corrections.

Arthur Bauville

Specific comments:

As stated above, the literature review is a bit authors-centric. I would like to suggest some readings to broaden a bit the introduction. I listed them at the end of this review.

1) **This is a good point. We now have included additional references throughout the manuscript.**

Fig. 2 and 5 are just used in passing, as a support to Fig. 3 and 4. They could be used a bit better. For example Fig. 2 could be the object of a small paragraph that discusses the dynamics of the experiment and the main events happening before to dive into Fig. 3. In addition, the pre-faulting and post-faulting phases are important events in Fig. 4. The limit pre-post faulting could be indicate on Fig. 2 as well.

2) **We agree that Fig. 2 and Fig. 5 deserve more attention. We now have discussed them in more detail (lines 278-286, lines 349-356).**

Methods A value for the basal friction in the glass and sand detachment experiments should be given here already (it's only given much later in the text).

3) **This important detail is in the Methods section 3.4 (line 223).**

5.59: "We calculated the incremental shear strain fields of each of the views of the sand pack using the curl of the incremental displacement field. " The curl of the incremental displacement field must be the vorticity*char_time, i.e., the rotational part of deformation instead of strain. In 2D the vorticity is a scalar while strain is a tensor. Please explain better what the quantity delta shear strain corresponds to: invariant of the incremental strain tensor? abs(vorticity)? 6.96. Following the previous comments, here, what do you call the shear strain field? the shear strain tensor field of the displacement curl field?

4) **For small angles of rotation, the tangent of that angle is equal to the angle. So, we can calculate the incremental shear strain as the absolute value of the curl of the incremental displacement field. We now include this specification in the methods (lines 166-170).**

Discussion 12.62-65. Here you argue that using lithostatic pressure as the traction on the fault may lead to underestimating Wfric. It would be nice to have an estimate of how much that is. For example, an upper estimate can be given by considering that sigma1 is horizontal and deviatoric stresses are such that yielding occurs. Doing some back of the enveloppe trigonometry on the Mohr-Coulomb diagram I get: Sigma_n = Sigma_mean-(Pl*sin(phi)*tan(phi))/sin(1-phi) where Pl is the lithostatic pressure and phi is the friction angle (you might want to double check my math). Using a friction angle of 30° it simplifies to Sigma_n = 2*Pl - (Pl*sin(phi)*tan(phi))/sin(1-phi).

That yields Sigma_n/Pl = 1.35; and at the end of the experiment Wext/(Wgrav+Wfric+Wint)=1.35. That's pretty nice :)

Sigma1 is probably not horizontal which gives you some latitude to put Wprop and Wseism.

5) **We agree that estimating the potential error induced by assuming lithostatic normal compression will benefit this analysis. We have now added a new figure (Fig. S5) showing the impact of using higher estimates of normal compression on the frictional work, and discuss this more thoroughly in the text (lines 395-399).**

Also, the discussion would be a bit more general if you expressed the deficit in percentage in addition to giving the values in mJ.

6) **We have now added this percentage (line 384).**

Technical corrections

2.42: Ritter et al., 2018 -> ref missing

7) **We have added this reference.**

3.72: "In these numerical accretion simulations, all of the work components increase during underthrusting. The development of the new forethrust increases Wint, but decreases Wfric by a greater degree, which correspondingly decreases Wext (Del Castello and Cooke, 2007)." The second sentence seems to contradict the first one.

8) We have corrected this mistake (lines 73-75).

4.05 Missing citation for Dotare et al., 2016. Possibly miscited. Do you mean this paper?: Yasuhiro Yamada, Tatsuya Dotare, Juergen Adam, Takane Hori, Hide Sakaguchi. Initiation process of a thrust fault revealed by analog experiments. Geophysical Research Abstracts, 2016, 18

9) We have added the correct reference (Dotare et al., 2016) to the list.

4.25. Reverse the order of citations

10) We have corrected this (line 134).

9.60. Fig. 3 is cited before Fig. 2. The paragraph can be easily rearranged to avoid that.

11) We have corrected this with a new paragraph (lines 280-286)

9.69. Earlier work could be cited (e.g. Vermeer, 1990)

12) We have added this reference (line 297).

9.88. Unneeded reference to Fig. 5B 9.93. There is no Fig. 5C 9.94 primary->primarily 10.5. Here you can refer to Fig. 5

13) We have corrected these mistakes (line 322, lines 349-354).

Minor comments on figures:

Fig. 3 Panel A has a lot of curves. The curve from exp E374 is hidden behind the others which is a bit unfortunate. Since E373 and E374 are the most important, the drawing order could be changed (i.e. as in the legend). Using thinner lines for E375, E376 could also improe readability Panel B etc-E the light blue curve is hard to distinguish from the grey background

14) We have modified this figure to improve clarity.

Suggested readings

Vermeer P. (1990). – The orientation of shear bands. – Géotechnique, 40, 223-234.

Le Pourhiet, Laetitia. "Strain localization due to structural softening during pres- sure sensitive rate independent yielding."Âa˘Bulletin de la Société Géologique de FranceÂa˘184.4-5 (2013): 357-371.

Dahlen, F. A. "Mechanical energy budget of a fold-and-thrust belt."Âa˘NatureÂa˘331.6154 (1988): 335.

Gutscher, MarcâA˘R˘André, et al. "Episodic imbricate thrusting and underthrusting: Analog experiments and mechanical analysis applied to the Alaskan accretionary wedge."Âa˘Journal of Geophysical Research: Solid EarthÂa˘103.B5 (1998): 10161- 10176.

15) We have now added additional citations to previous work throughout the manuscript.