Solid Earth Discuss., 7, C717–C721, 2015
www.solid-earth-discuss.net/7/C717/2015/

Interactive comment on "Evolution of a highly dilatant fault zone in the grabens of Canyonlands National Park, Utah/USA – integrating field work, ground penetrating radar and airborne imagery analysis" *by* M. Kettermann et al.

F. Balsamo (Referee)

fabrizio.balsamo@unipr.it

Received and published: 2 June 2015

Parma (Italy), June 4th 2015

Dear Editor,

this is my review of the Research Article MS No. se-2015-24 "Evolution of a highly dilatant fault zone in the grabens of Canyonlands National Park, Utah/USA – Integrating field work, ground penetrating radar and airborne imagery analysis" by M. Kettermann et al.

The manuscript deals with the analysis of dilatant fault zones in the grabens of Canyonland National Park in Utah (USA). Extensional fault zone architecture and is an important issue in structural geology, with application in petroleum geology and hydrogeology.

The authors investigated a very broad area integrating airborne imagery analysis with field observations and ground penetrating radar technique in 4 selected grabens. Results presented in the paper are sound and the final evolutionary model is consistent with presented data.

The model display an interesting mechanism for extensional faulting in very shallow depth, which involve significant dilation for faults with small to moderate displacement developed in an etherolithic sequence.

I suggest the paper is suitable for publication after some minor to moderate revision which mainly concern with terminology used, figures editing, and some text clarifications. Major and minor points to address are listed below approximately in the order of appearance in the MS.

Kind regards,

Fabrizio Balsamo

Major points

1) Orthogonal joints

In Figure 4 - and page 1126 (lines 15-24) - there are rose diagrams and photographs showing faults/joints orientations. Joints are either parallel and orthogonal to fault strike. Fault-perpendicular joint are also particularly abundant and well-developed in domains 1 and 2. Although fault-perpendicular joint sets are common in many extensional fault zones developed in several geological contests, in this MS there are no mention about this fault-perpendicular joint set, and no explanation about their origin. I am wondering if they can be integrated in the model proposed by the Authors.

A possibility is that such joints, if genetically associated with the extensional faults, are related to the lateral propagation of fault zones which induce a component of stretching parallel to fault strike. Also the tensile stress associated with the bending of down throwing hanging-wall perpendicular to the fault strike could locally induce orthogonal joints. Maybe some bedding dip-domain around studied fault zones could help to solve this issue.

You may found more info and references about fault-orthogonal joints in the reference below:

Destro, N.,1995. Release fault: a variety of cross fault in linked extensional fault systems, in the Sergipe-Alagoas Basin, NE Brazil. Journal of Structural Geology 17 (5), 615–629, 1995.

Kattenhorn, S.A., Aydin, A., Pollard, D.D., et al., 2000. Joints at high-angles to normal fault strike: an explanation using 3-D numerical models of fault-perturbed stress fields. Journal of Structural Geology 22 (1), 1–23.

Balsamo, F., Storti, F., Piovano, B., Cifelli, F., Salvini, F., Lima, C. (2008). Time dependent structural architecture of subsidiary fracturing and stress pattern in the tip region of an extensional growth fault system, Tarquinia basin, Italy. Tectonophysics, 454, pp. 54-69.

2) Terminology used

Please clarify the term "faulted joint surface", which is expected to be a joint surface subsequently sheared and that, due to shear, accommodate some displacement along the surface. In your case (model), joints remain joints and are passively translated and opened (dilated) due to underlying extensional faulting, so that they show throw and heave. This is explained in the text, but should be clear from the beginning of data presentation to avoid confusion.

Minor points

Page 1121, line 10: I would remove "in profile" Page 1121, line 23-24: what exactly you mean by "produce a mechanical stratigraphy"? please clarify. Page 1122, line 2: which type of reservoir? I would add "sandstone" reservoir. Page 1122, line 16: remove "/", use ",". Page 1127, line 1: add "sites" after Canyon. Page 1127, line 10-11: remove "(" before Biggar, and put in brackets the year (1987) of publication. Page 1127, line 12-13: Remove this sentence, already mentioned: "They were mapped from field observations and orthoimages (for map distribution see Fig. 3)." Page 11278, line 8: you say that throw is 38.5 m, but in Fig. 6A is 38.7 m. Please correct the wrong value. Page 1128, line 9: you say about 25 m, but in Fig 6A is ∼20 m. Please correct. Page 1128, line 18: add dipping between "shallow" and "fault" (shallow dipping fault). Page 1128, line 20-27: remove "ourselves". COncepts are conffused here, al least for me. Not clear whether you found or not calcite fibers on joint surfaces. Furthermore, the term "faulted joint surface" means that you have a joint which is subsequently sheared. I would pay attention to terminology used. Clarify that your joints are pure tensile fractures with no shear movements (and no slickenlines, fibers, ...). Page 1132, line 24: "Evidence for dilatant faulting is the occurrence of sinkholes...". OK, but maybe give some more details (like for example dimensions of sinkholes). Page 1133, line 5: same comment as above about "faulted joint surface". If I understood correctly, along these joints you do not have any shear evidence, but they accommodate significant offset and dilation. So I am not sure you can call them faulted joints. I would call joints, explaining that you have offset accommodated along them. Page 1133, line 16: could you say at which depth you have - or you expect - the change in dip of the faults? Furthermore, I would say "requires the presence of non-vertical faults in depth" instead of " change in dip of the faults ". Page 1135, line 24: Fig. 14. In this figure we see faults dipping ∼80°, not subvertical joints. Is this correct? Faults accommodate shear displacement, so one could expect some striations and slickenlines along fault surfaces. This evidence affect your Fig. 15 model? Page 1136, line 6: "Faults dip with 60-80°", remove "with", say in which level/lithology they are developed. Page 1139, line 24: "fault-joint intersection", do you mean interaction? What exactly mean fault-joint intersection in your model of

Fig. 15?

Figures

Figure 1. This figure concerns with field photographs, without any geological feature indicated (for example graben, fractures). Maybe would be nice to add some structural features. Also in the caption there are only geographical information, no geological explanation.

Figure 2. Within the geological map of SE Utah there is a rectangle which indicate the investigated area. This rectangle is referred as Fig. 2, while it is the 3rd figure. Accordingly, change 2 with 3.

Figure 4. Add "number of data" in each rose-diagram pertaining to joints and faults measured in each 1 to 4 domain. Moreover, what the grey arrows represent in top left image? Explain in caption.

Figure 6. Would be possible to drawn in dotted lines some faults/fractures (inferred) responsible of the visible offsets? Is not possible that the "heave" parameter is overestimated due to preferential erosion of rocks along fractures?

Figure 7. In caption, what you exactly mean by "joint surfaces at faults"? please clarify. This joint shows plumose structures?

Figure 8. Font size in this figure is too small, and probably not visible in a printed version (at least mine). I suggest to enlarge font sizes up to 7 (minimum). In the western part of the section of GPR profile in "C" there are evidence of growth strata suggested by the green lines. Is this correct? any comment in the text?

Figure 9, 10, 11. Font size in this figure is too small, and probably not visible in a printed version.

Interactive comment on Solid Earth Discuss., 7, 1119, 2015.