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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.

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Dear Andrea Billi,

thank you very much for the positive review. In the following I will provide detailed responses to your comments as suggested by the review process. I hope we addressed your suggestions to satisfaction. Changed and new figures are attached.

Kind Regards,

Michael Kettermann

(1) the GPR profiles are probably the most important data in this manuscript. I have had some difficulties in seeing, reading, and understanding these profiles. The profiles are often too small and the interpretation is too simple. I suggest the authors to work on the graphic representation of these profiles enlarging them or using portion enlargement and greatly enriching the line drawing and interpretation. As they appear in the manuscript, these profiles are not enough compelling for the proposed final model.

–> We split the aerial photos from the radargrams and changed the orientation of the latter so they fill a whole page. Additionally, we enhanced the line drawings and changed the background of the drawings to transparent grayscale. This results in 3 more figures, but increases the quality.

(2) Dilatant fault zones are well known structures but not so common. Kettermann et alii rightly provide a series of comparative examples from other settings so to support their model. I totally agree with this method. I suggest the authors to reinforce this comparative method. I was wondering whether Kettermann et alii could add a synoptic figure, where they could show other significant examples similar to their study area. This figure could display images or re-drawing from previous papers. In other words, I am suggesting Kettermann et alii to strengthen a little bit the comparative analysis concerning dilatant fault zones and related graben formation.

–> We added the following paragraphs to section 7.2. along with a Figure comparing different fault geometries depending on whether or not they are affected by joints :

"Kettermann and Urai (2015) studied the lateral geometry of brittle faults in analogue models using hemihydrate powder. They described a rough and patchy geometry with relays and large blocks rotating into the fault as a result of linkage of fault segments. Similar features are described in basalts of Hawaii by Holland et al. (2006). "

"It is however possible, that joints subparallel to a basement fault form as initial stage of deformation (e.g. Destro, 1995; Kattenhorn et al., 2000; Balsamo et al., 2008). Later the main faults from underneath can localize along these early formed joints and accommodate offset as observed by Grant and Kattenhorn (2004). These joint related faults can look quite similar to the faults described in this paper; however the joints are always slightly inclined to the faults."

"In general, as both faults with and without pre-existing vertical joints can form vertical extension fractures at low overburden stresses, the main difference is the lateral geometry. Without pre-existing joints the heterogeneity of the rocks defines the position of individual fault segments in an early stage that link (hard link or soft link) with increasing displacement and finally form typical faults with relays and fault blocks. With pre-existing joints the fault geometry is widely controlled by the joint pattern as it is the case in parts of Iceland or the Canyonlands. Figure 17 illustrates the effects of different prerequisites of a faulted region."

(3) Again to make their conclusions more solid and sound, I suggest Kettermann et alii to provide a better ÂńnegativeÂż analysis of their data and results. In other words, can their results be interpreted in a different way? Yes/no and why? Why previous models for the same study area should be outpaced by this model?

–> We added the following paragraphs to the discussion to enhance the argumentation:

Section 7.2: "However, erosion at the fracture surfaces may lead to overestimation of the heave and result in underestimation of fault dips. For a detailed correction of erosion the exact timing of fracture opening and erosion rates over time would be needed which is beyond the scope of this work. An underestimation of fault dips does not have an effect on the proposed model."

Section 7.3:"The amount of graben internal faults might be slightly overestimated by GPR profiles since these faults propagate upwards from the brittle basement through several tens of meters of sediments in which the faults refract and form branches. The GPR profile in Devils Lane for example shows several faults that do not reach to greater depth as well as some blind faults that are restricted in depth."

End of Section 7.3: "Similar models were proposed by Schultz-Ela and Walsh (2002) and Walsh and Schultz-Ela (2003) based on numerical modeling, although disregarding the vertical joint sets. We show the importance of the joints on the evolution of the fault system and extend their models by providing direct field evidence for all features including the strong effect of the vertical joints from GPR profiles, field observation and remote sensing."

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

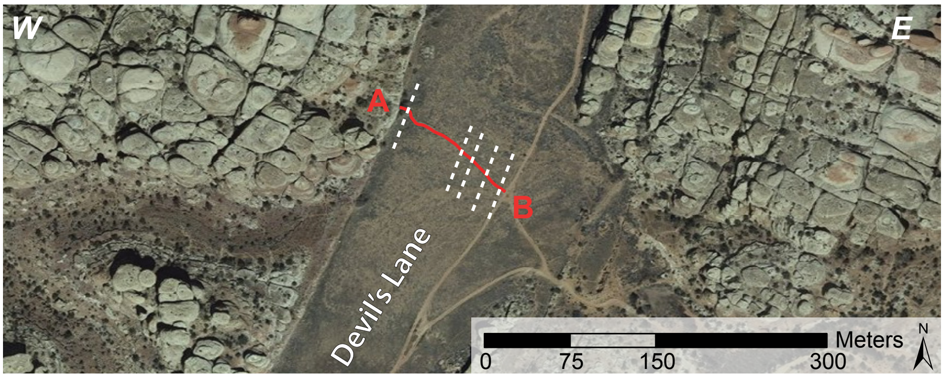

W
E
A
B
Devil's Lane
Meters
0
75
150
300
N

Fig. 1.

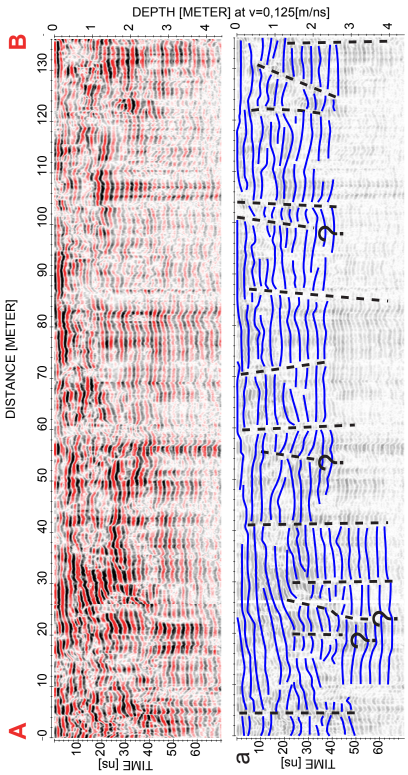

DEPTH [METER] at v=0,125[m/ns]
DISTANCE [METER]
TIME [ns]
A
B
a

Fig. 2.

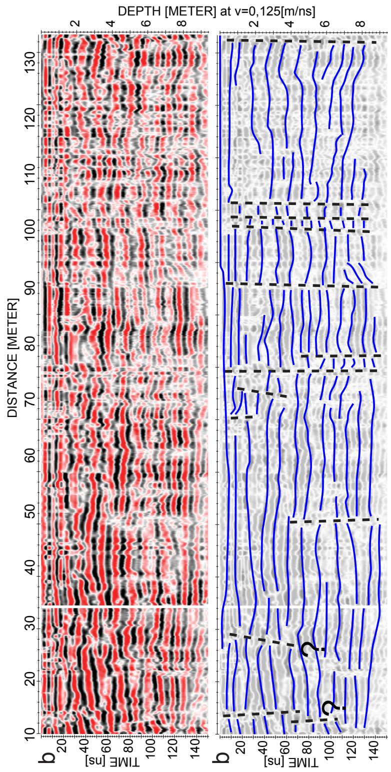

DEPTH [METER] at v=0,125[m/ns]
DISTANCE [METER]
TIME [ns]
b

Fig. 3.

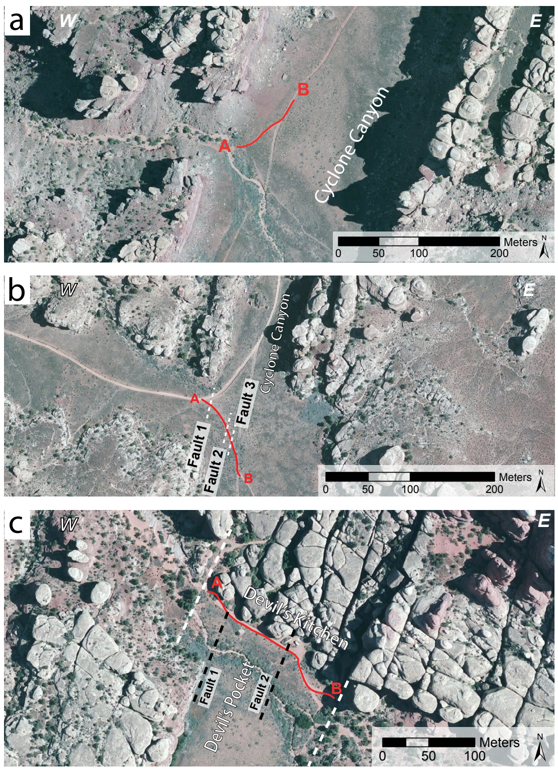

a
W
E
A
B
Cyclone Canyon
Meters
0 50 100 200
b
Cyclone Canyon
Fault 1
Fault 2
Fault 3
c
Devil's Kitchen
Devil's Pocket
0 50 100

Fig. 4.

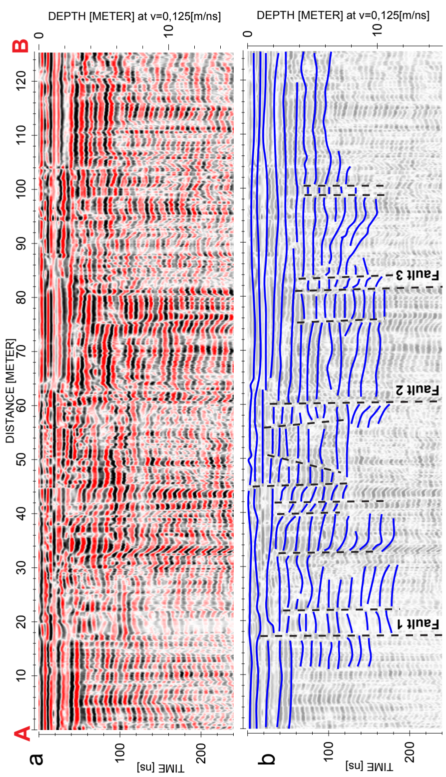

a
b
A
B
DISTANCE [METER]
DEPTH [METER] at v=0,125[m/ns]
TIME [ns]
Fault 1
Fault 2
Fault 3

Fig. 5.

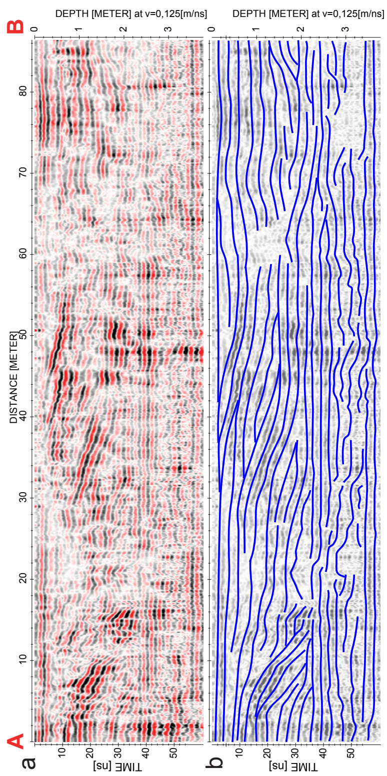
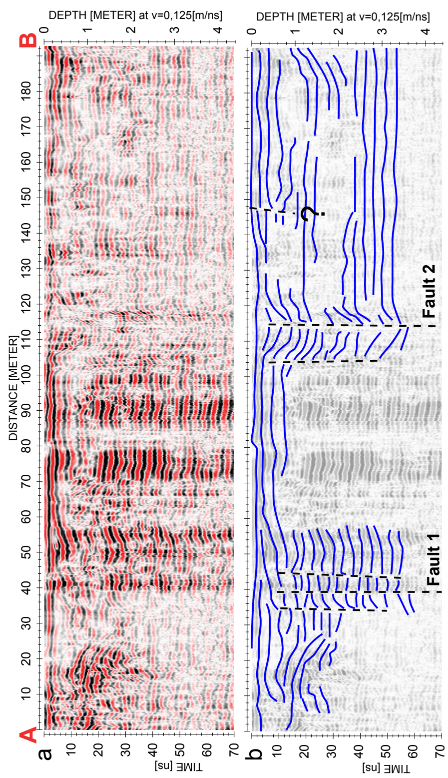
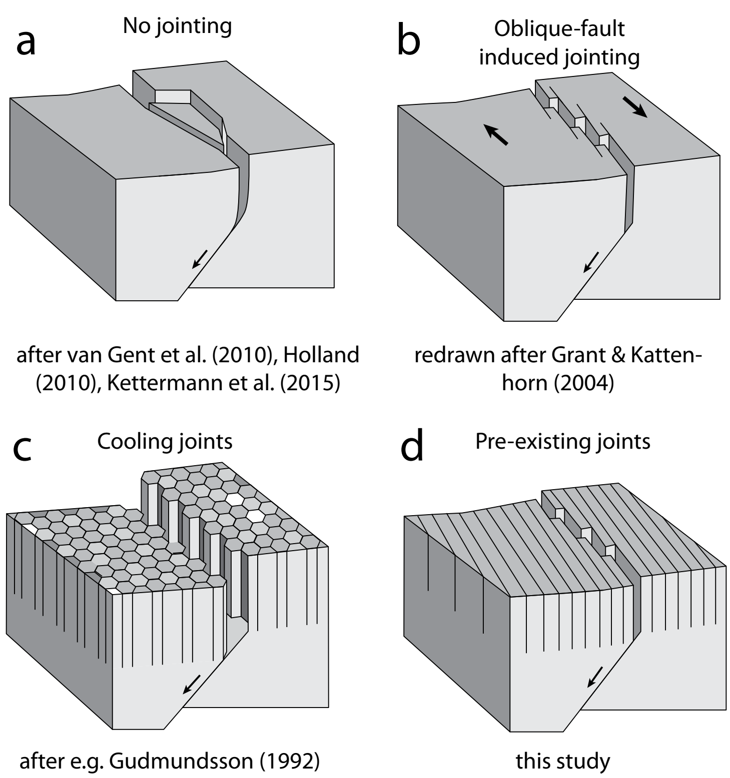

a
b
A
B
DISTANCE [METER]
DEPTH [METER] at v=0,125[m/ns]
TIME [ns]

Fig. 6.



DEPTH [METER] at v=0,125[m/ns]
DISTANCE [METER]
TIME [ns]
Fault 1
Fault 2
A
B
a
b

Fig. 7.



a
No jointing
after van Gent et al. (2010), Holland (2010), Kettermann et al. (2015)
b
Oblique-fault induced jointing
redrawn after Grant & Katten-horn (2004)
c
Cooling joints
after e.g. Gudmundsson (1992)
d
Pre-existing joints
this study

Fig. 8.

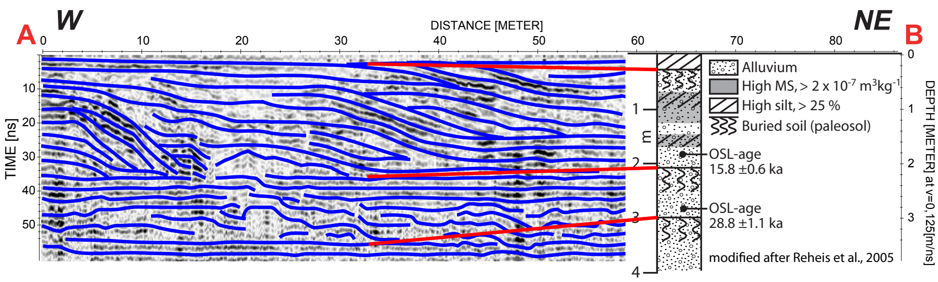

A
W
DISTANCE [METER]
NE
B
0
10
20
30
40
50
60
70
80
TIME [ns]
DEPTH [METER] at v=0.125[m/ns]
Alluvium
High MS, > 2 x 10-7 m3kg-1
High silt, > 25 %
Buried soil (paleosol)
OSL-age
15.8 ±0.6 ka
OSL-age
28.8 ±1.1 ka
modified after Reheis et al., 2005
m

Fig. 9.