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Solid Earth
Discussions

Interactive comment on "The seismogenic fault system of the 2017 M_w 7.3 Iran-Iraq earthquake: constraints from surface and subsurface data, cross-section balancing and restoration" *by* Stefano Tavani et al.

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Point 1 This is a nice structural reconstruction of the western Zagros, integrating 2017 earthquake data. The main issue is a fixation on the earthquake taking place on a N-S segment of the MFF (Mountain Front Fault). Brief mention is made of the N-S structure being separate – the Khanaqin Fault, but this is then strangely ignored. In fact, it looks very likely that the earthquake took place on the Khanaqin Fault – and is distinct from NW-SE fault segments grouped as the MFF. This is a significant aspect of the regional geology, which should be emphasised rather than underplayed. Response

The main-shock and the Khanaqin fault are about 20 km apart. We will show this in figure 3.

Point 2 The root of the problem is that the Zagros faults get depicted in different ways. One view is to emphasise their continuity, so that the MFF, HZF etc get drawn as continuous structures over 100s of km (see Berberian et al 1995). If these faults are offset by N-S right-lateral faults, the offsets are sometimes depicted as up to 100s of km (see Berberian again), but more detailed work shows that such offsets are only a few km (Authemayou et al., 2006). However, the faults are much more segmented than this "Himalayan" style – see work by Walker, Ramsey et al, with segments typically no more than 20-40 km, rupturing in M 5-6 earthquakes. The fault segments linked together as the "MFF" are not a Himalayan-style nappe, but equivalent steps in the relief and geomorphology of the range. Response We did not make this part very clear. We have never supported the idea that the mountain front fault is a continuous structure. Indeed, what we have drawn in figures 1, 2, and 3 is the trace of the mountain front flexure. However, in figures 1 and 2 we have used for the flexure the same pattern as for the faults, and this has created some misunderstanding. Figures 1 and 2 will be modified accordingly.

Point 3 Therefore the Tavani et al paper needs to consider the consequences of the N-S Khanaqin Fault being a separate, N-S structure to the main NW-SE thrusts, which slipped in the 2017 earthquake in a highly unusual manner for the Zagros – witness the sheer size of the event, which is much larger than typical Zagros thrust earthquakes. See Lawa et al (2013) and Allen et al (2013) for examples of Zagros structure maps that include the Khanaqin Fault. The geology descriptions and structural sections look very good, but this issue of fault segmentation and the existence of the Khanaqin Fault means that they need more work. Response We will add the trace of the Khanaqin fault in figure 3. We will also remark that: (1) the Khanaqin fault cannot be the source of the 7.3 earthquake (see point 1), (2) this fault coincides with the backthrust seen at the SW termination of the section (figures 5 and 6).

Point 4 The early part of the paper describes the 2017 earthquake parameters, but another way of doing this is to quote the slip vector azimuth of the event, which is 90 deg. from the auxillary plane strike, ie towards 212 deg. by my calculation. This means highly oblique slip on the fault, and also that the section line in figure 6 is covering faults with very different orientations, from the conventional NW-SE thrusts to the more N-S Khanaqin Fault. Neither of these points comes across properly in the paper. Response The slip vector is more precisely the plane containing the T and P axes, which is also perpendicular to the two nodal planes. This is 215° striking and 78° dipping. As quoted at page 10, the orientation of the section is N49°, i.e. at 14° with respect to the co-seismic slip direction. This direction was chosen because balanced cross-sections must run parallel to the tectonic transport direction, this to ensure the absence of out of plane motion (as quoted in the text). This is a well-established procedure and does not need any further clarification. Concerning the fact that the strike of the nodal plane is oblique to the trend of our section, this is merely because the low-dipping fault is a lateral ramp, and cross-section along lateral ramps must run parallel to the transport direction. Also this basic principle does not need clarification in the text. Concerning the fact that the section runs oblique to the N-S Khanaqin fault, we remark that if this fault exist, it is a second order accommodation structure, and the section must run perpendicular to the main structures.

Point 5 It would help if the Khanaqin Fault trace was properly drawn on Figures 2 and 3. The authors seem to have taken the continuous, sinusoidal, lines drawn on many regional papers for the Zagros, but, as noted, there are plenty of other papers that try to draw the Khanaqin Fault more accurately. Response Done. Added on figure 3.

Point 6 Where Tavani et al make an improvement on our knowledge is that the try use the 2017 earthquake data to interpret the fault for the first time at depth, as a lateral ramp: this point stands, despite their confusion over the structure being part of the "MFF". See also Koshnaw et al 2017 for a cross-border geology map that means figure 3 can be improved. Response We will quote Koshnaw et al 2017.

Point 7 A lat/long label in fig 3 should be 45/45 E not 45/45 N. Response Done.

Point 8 Page 3: This structure is thus a candidate... Response Done.

Point 9 The first part of p 15 is critical, as the authors make a good description of the likely regional structure - but this is not apparent on their maps or cross-sections! Response We now explained our view on the N-S striking Khanaqin Fault. If this fault exist, it is the backthrust imaged at the SW edge of the seismic line in figure 5. Accordingly, we have added this at page 13 (Balancing the cross section) "The position of such a back-thrust roughly coincides with the Khanaqin Fault (e.g. Lawa et al., 2013) (Fig. 3), which accordingly must be downgraded to accommodation structure of the Mountain Front Fault"

In the discussion, at page 15, we have added: "As previously mentioned, the N-S striking Khanaqin Fault (e.g. Berberian, 1995; Hessami et al., 2001; Lawa et al., 2013; Allen et al., 2013), in our structural reconstruction becomes an accommodation structure of the Mountain Front Fault."

The back thrust is also labelled Khanaqin Fault in figure 6.

Please also note the supplement to this comment:
https://www.solid-earth-discuss.net/se-2018-21/se-2018-21-AC2-supplement.pdf

Interactive comment on Solid Earth Discuss., https://doi.org/10.5194/se-2018-21, 2018.

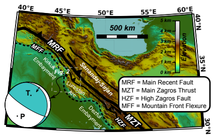

Figure 1 (Single column)
Tectonic sketch map of the Zagros Mts., showing epicenter and moment tensor of the November 12, 2017 Mw 7.3 earthquake (source USGS, https://earthquake.usgs.gov/)

Fig. 1.

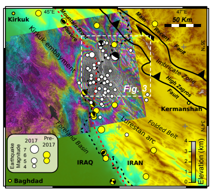

Figure 2 (Single column)
Elevation map (source ESDIS) showing the main structural features of the Lurestan region and earthquake distribution (source USGS, https://earthquake.usgs.gov/). Mw > 4 earthquakes of the November 2017 sequence are reported in white; pre-2017 Mw > 5 earthquakes are reported in yellow. The Sentinel 1 co-seismic interferogram (Nov. 11, 2017, 3 p.m. UTC to Nov. 17, 2017, 2:59 p.m. UTC; http://sarviews-hazards.alaska.edu/Event/34/) is also shown as an overlay.

Fig. 2.

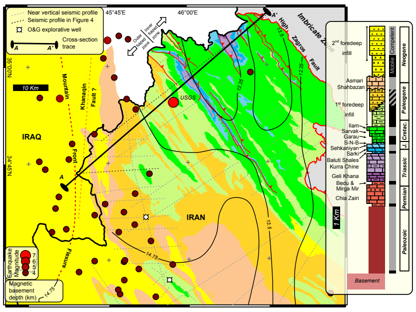

Figure 3 *(Double column)*
Geological map of the NW portion of the Lurestan region (source: National Iranian Oil Company and original field mapping) showing: (i) November 2017 earthquakes; (ii) traces of near vertical seismic sections and wells used to constrain the geological cross-section of figure 6 (sections shown in figures 4 and 5 are in black); (iii) magnetic basement depth (Teknik and Ghods, 2017), and (iv) trace of the section in figures 4 and 5. The inset shows the stratigraphic succession of the area, with thicknesses for the Mesozoic to Cenozoic stratigraphic units computed from original field data. Thickness for the Paleozoic to Lower Triassic is taken from the literature on the geology of Iraq (Jassim and Goff, 2006). The supposed trace of the Khanaqin fault is from Lawa et al. (2013)

Fig. 3.

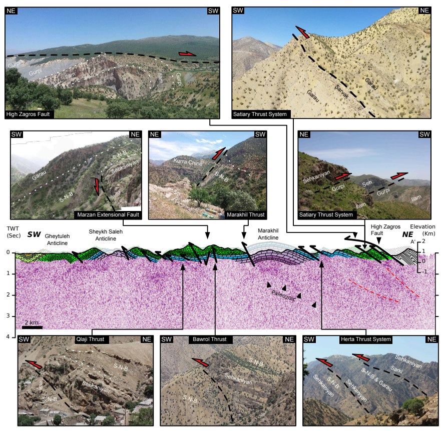

Figure 4 (Double column)
NE part of the NE-SW oriented geological section across the hypocentral area, with field photographs illustrating the main structural features. A near vertical seismic profile is displayed below the cross section (vertical scale is roughly equal to the horizontal scale).

Fig. 4.

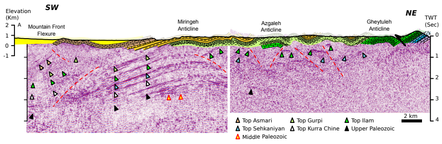

Figure 5 (Double column)
SW part of the NE-SW oriented geological section across the hypocentral area. Near vertical seismic profiles are displayed below the cross section (vertical scale is roughly equal to the horizontal scale).

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Fig. 5.

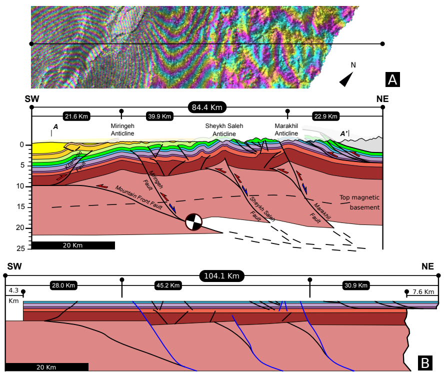

Figure 6 (Double column)
(A) Balanced cross-section along the direction of the section in figures 4 and 5, showing projected main shock and detail of the co-seismic interferogram with trace of the section. (B) Restored section.

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Fig. 6.