Distributed deformation in the Zagros fold-and-thrust belt: insights from geomorphology

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1 Outline

The Zagros fold-and-thrust belt (Fig. 1) is sometimes represented to have only a few major thrusts. These thrusts are oriented along strike of the range and rarely associated with major structural relief and/or surface rupture during earthquakes.
The seismicity record, published data from the hydrocarbon industry and field observations and geomorphic analysis in the Kirkuk Embayment shed light on the evolution of structures and the involvement of basement (Figs. 2 and 3).

Using the Hypsometric Integral (HI) Index and the seismicity record, we investigate the distribution of deformation and the landscape response, to determine whether there are abrupt changes in HI, consistent with activity of a few major thrusts, or gradational. The results show distributed deformation on numerous smaller faults, rather than major uplift on a small number of laterally continuous nappes, as it seen in Himalya and Longmenshan.

Methods and Data processing

1. Geomorphic analysis, represented by Landscape maturity index (Fig. 2).

2. Fieldwork observation for groundtruthing (Fig. 4).

3. Balanced cross section construction to calculate the shortening of the area (Fig. 3).

4. Regional geomorphic analysis represented by the hypsometric integral of drainage basins for the orders 3, 4, 5, and 6 (Fig. 6).

5. Software and data: ArcGIS 10.3.1, MATLAB based TecDEM, SRTM 1 and 3arc.

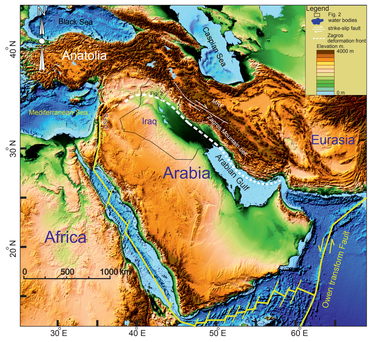

Fig. 1. Regional tectonics of the Arabia-Eurasia collision. Dashed line = Zagros deformation front. MRF, Main Recent Fault; DSFS, Dead Sea Fault System.

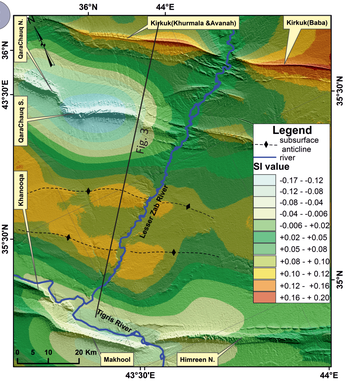

Fig.2. Surface Index (SI) map reveals different levels of landscape maturity (Obaid and Allen,2016): in review.

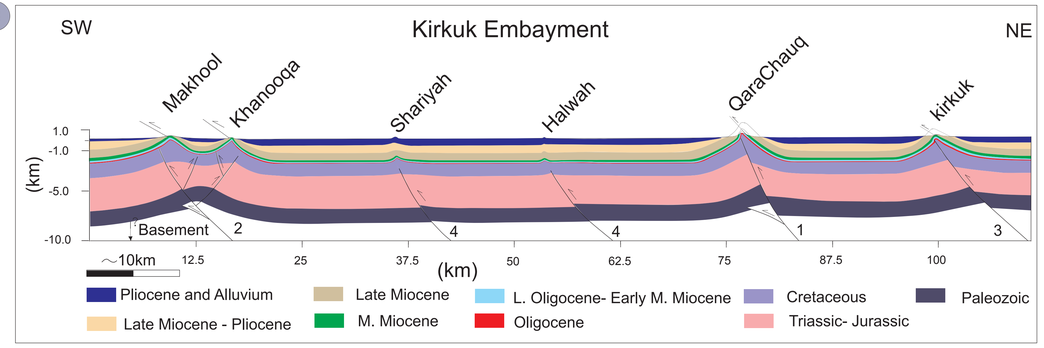

Fig. 3. Balanced cross-section produced using earthquake data, fieldwork, and geological information from GEOSURV, Iraq, in addition to the maturity index used in Figure 2. The effect of basement faults is inferred from the maximum depth of earthquakes (20 km). Numbers refer to the order of faulting which is the order of folds growth.

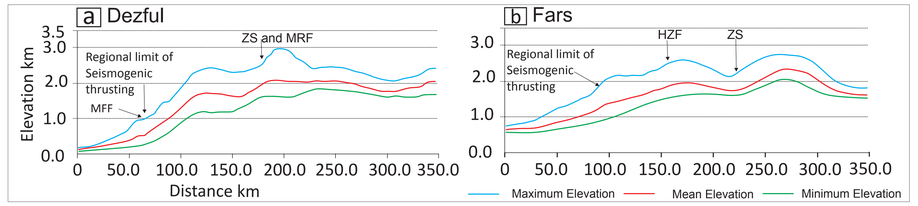

Fig. 5. regional swath profile (a and b) showing the steep and gentle gradient for the Dezful and Fars region respectively.

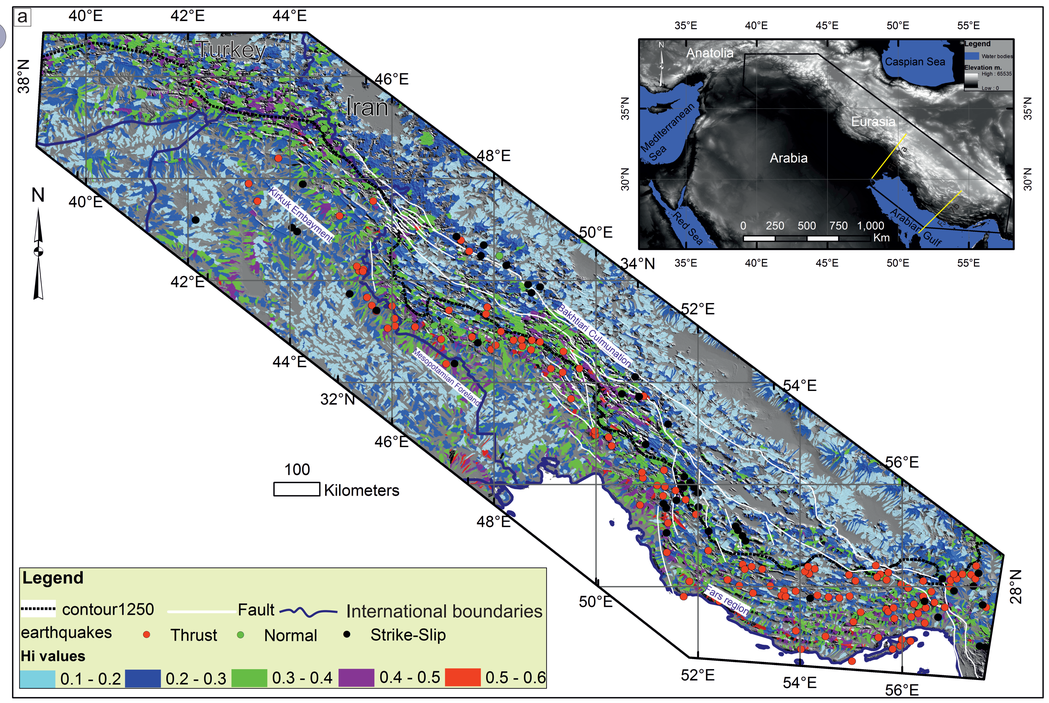

Fig. 6. HI values for the third order drainage basins of the Zagros, overlain by the location of major epicentres. Note the cut-off of thrust seismicity at ~1250 m (Nissen et al., 2011). For the third order basins there is a broad region of high HI along the Zagros, between the Iranian Plateau and the foreland. Specific regions show variations in this broad trend. In the Bakhtyari Culmination, the high/low HI transition lies above the thrust seismicity cut-off. In the Fars region, the high/low HI transition takes place below this cut-off. We interpret the different regions as having different landscape responses to tectonic forcing, largely controlled by the role of basement structure: deformation in the Bakhtyari Culmination is spatially restricted by the adjacent, strong strain, Dezful Embayment. No such constraint operates in the Fars region.

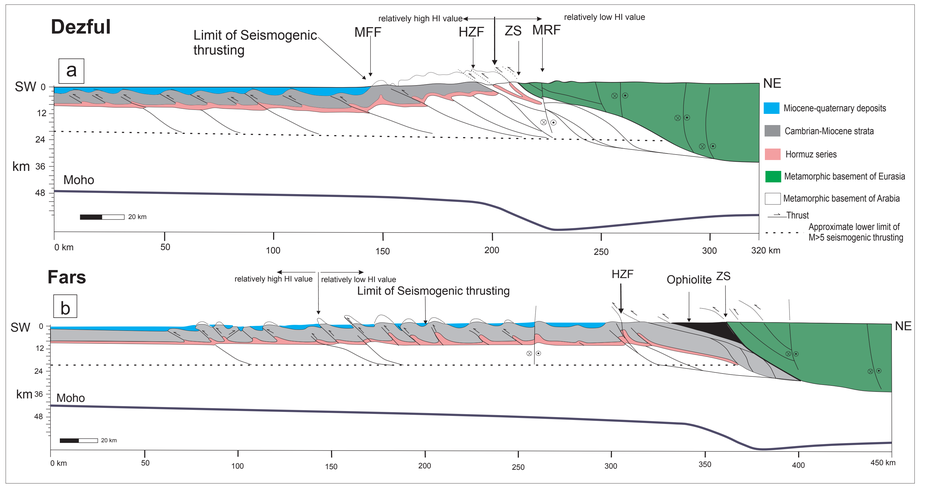

Fig.7. Balanced cross-section across the Zagros a and b for the Dezful and Fars region respectively (after Allen et al., 2013). The figures show the major structure of the Zagros and the relation between the relief, gradient and seismicity with the HI. Abbreviation: MFF, Main Front Fault; MRF, Main Recent Fault; HZF, High Zagros Fault; ZS, Zagros Suture; HI, Hypsometric

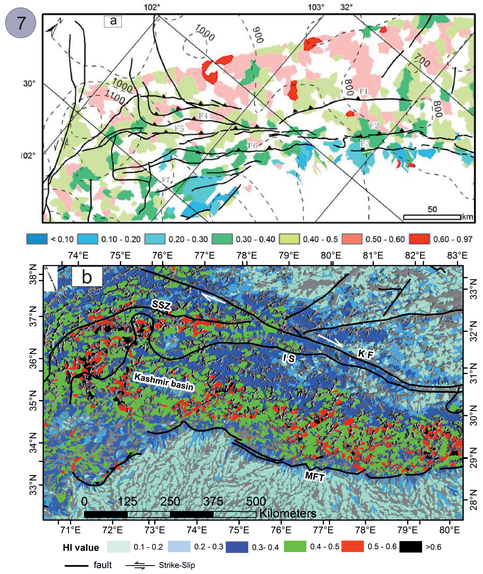

Fig. 8. A comparison between the Zagros and two areas from the margin of the Tibetan Plateau (a and b). a) HI values distribution for the fifth order drainage basins of the Longmenshan/ eastern Tibetan plateau (Gao et al., 2016). b), HI values for the third order drainage basins western Himalaya. Note the sharp boundary between the High and Low HI values along the F2, Beichuan-Yingxiu fault, F6, Shuangshi-Dachuan fault, the STD, south Tibetan Detachement and the MFT, Main Frontal Thrust. This style is not found in the Zagros where several faults with different orientations occupy the zones of high HI rather than one propagation front towards the foreland.

8 Conclusions

Geomorphic surface indices provide new insights to help in understanding fold growth sequence when the climate and rock type are semi constant.

In Dezful region the limit between the high HI and low HI is situated NE from the position of the seismogenic thrusting limit while it is stepped back SW of the seismogenic limit in the Fars region. This might related to basement control of the active thrusts.

The distribution of the Hypsomertic Integral values show that the SW quasi-continuous progression of deformation in the Zagros is not correct. This can be inferred from the absence of sharp boundaries between the different groups of HI values along the Zagros Orogen.

The Himalaya and Longmenshan examples show that the major tectonic structures (faults) play an important role in separating the area into high and low HI which is different than the case in the Zagros. The Zagros display gradual changes in the values of Hi along short segments of numerous faults but not abrupt changes along strike of major faults.

References

Nissen, E. Tatar, M., Jackson, J. A., Aleen, M. B., 2011.New views on earthquake faulting in the Zagros fold-and-thrust belt of Iran. Geophysical Journal International 186, 928–944.
Gao, M. et al., 2016. Active tectonics evaluation from geomorphic indices for the central and the southern Longmenshan range on the Eastern Tibetan Plateau, China. tectonics, 35, 1812-1826.
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