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Effects of secondary static stress triggering on the spatial distribution of aftershocks, a case study, 2003 Bam earthquake (SE Iran)

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Contents

Introduction

- ❖ The 2011 M6.3 Christchurch earthquake demonstrated that aftershocks could be more damaging than their main shock (Kaiser et al., 2012).
- ❖ following an earthquake in order to the implementation of planning search and rescue activities we need an operational aftershock forecasting model.
- ❖ One of the successful models that could forecast the spatial distribution of the aftershocks and next main shocks is Coulomb stress changes (e.g. Toda et al., 1998; Asayesh et al., 2018)..

- ➢ Although there is a good correlation between positive stress changes, , the existence of aftershocks in stress shadows in various case studies remained unaddressed.

- ➢ The static stress changes caused by the small earthquakes (secondary aftershocks stress) cannot be ignored and taking account of stress changes due to small earthquakes in order to reassess the validity of the static stress triggering hypothesis is necessary (Meier et al., 2014; Nandan et al., 2016).

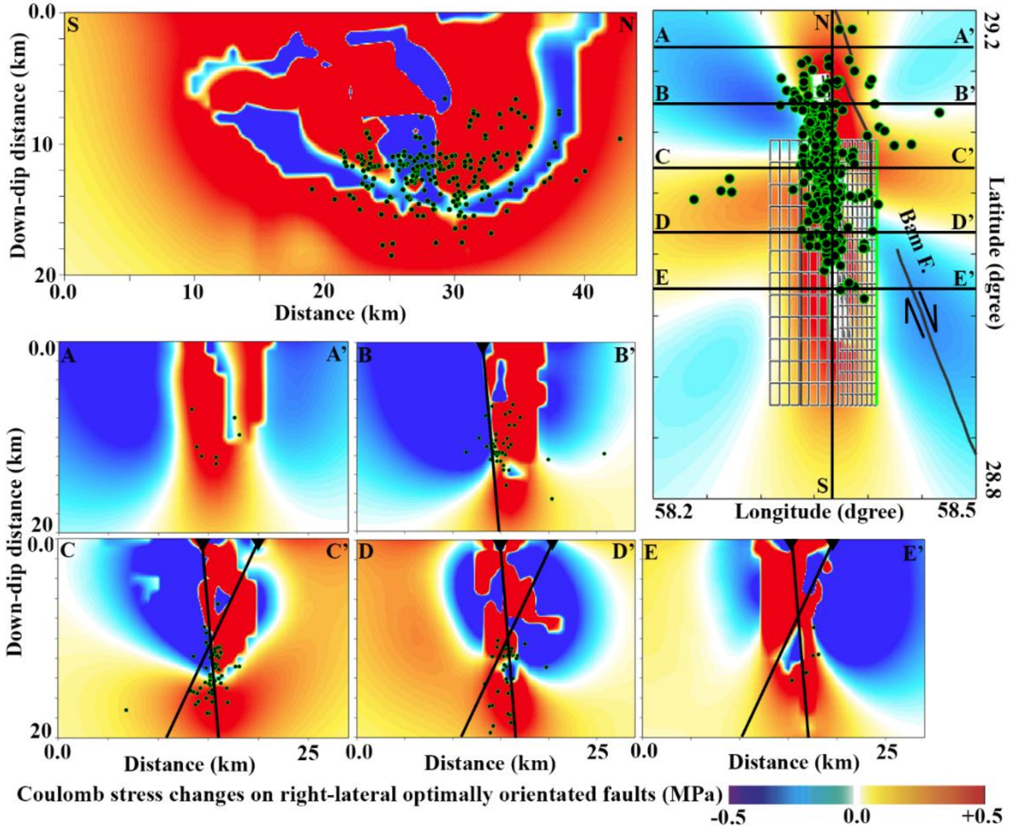


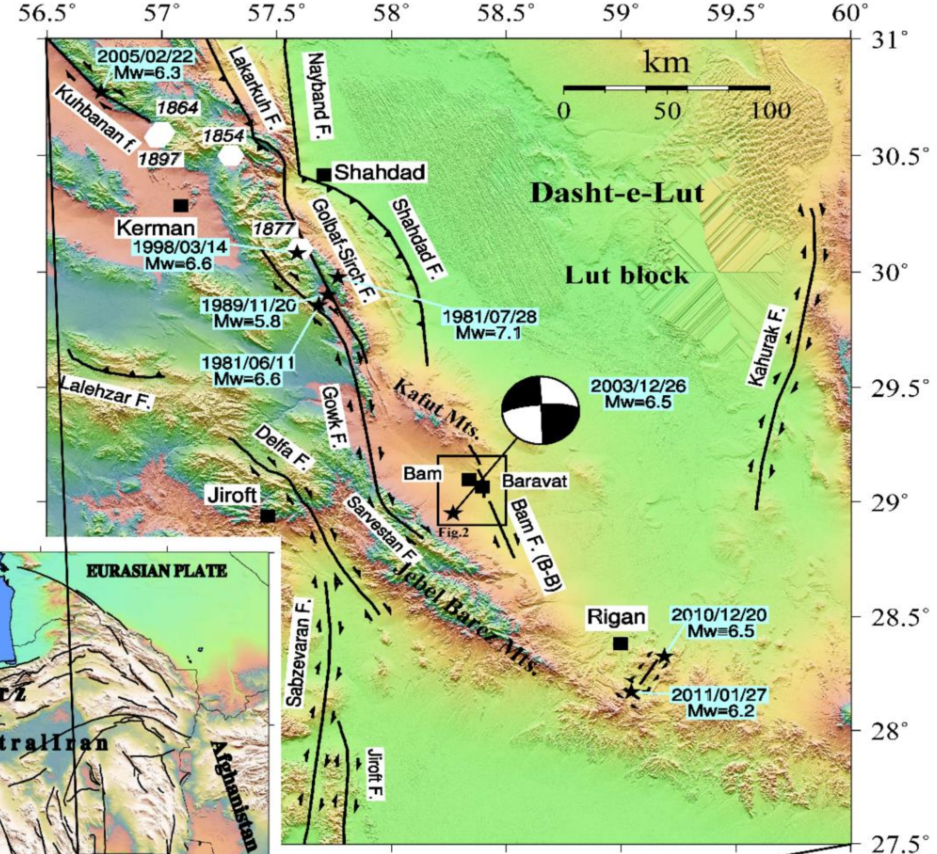
Figure 1. Coulomb stress changes due to Bam earthquake and aftershocks distribution.

Case study

- ❖ On the early morning of Friday, December 26, 2003, the Bam city with a population of around 150000 in the south-eastern part of Iran experienced one of the worst earthquakes in Iranian history.

- ❖ This very strong earthquake (Mw 6.6) with about 26,500 victims, 30,000 to 50,000 injured, and more than 100,000 homeless was one of the most destructive, disastrous and tragic event in the recorded history of Iran.

- ❑ Good-variable slip models (Funning et al., 2005) and high-quality focal mechanisms and hypocenters (Tatar et al., 2005) enabled us to investigate the role of small to moderate earthquakes in static stress triggering of aftershocks during the Bam earthquake.



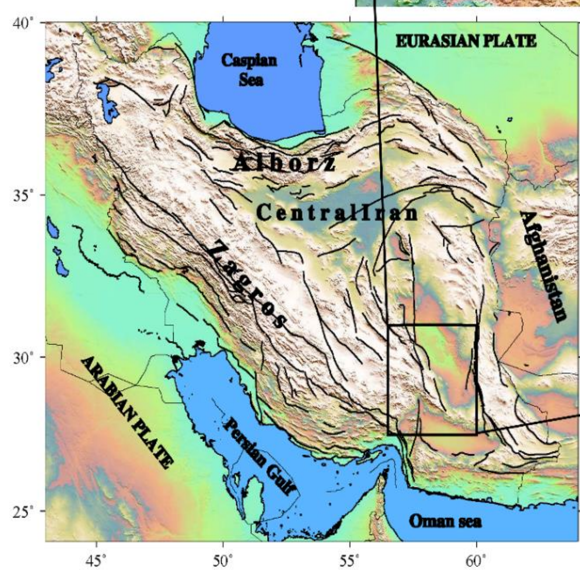


Figure 2. Main tectonic features of south-east of Iran. Location and focal mechanism of the Bam earthquake.

Data

Aftershocks

- ❑ **158 focal mechanism from Tatar et al. (2005) with Mw >1 (A minimum of 10 observation, azimuthal gap less than 180°, and location errors less than 1 km) are considered for secondary stress triggering calculation.**

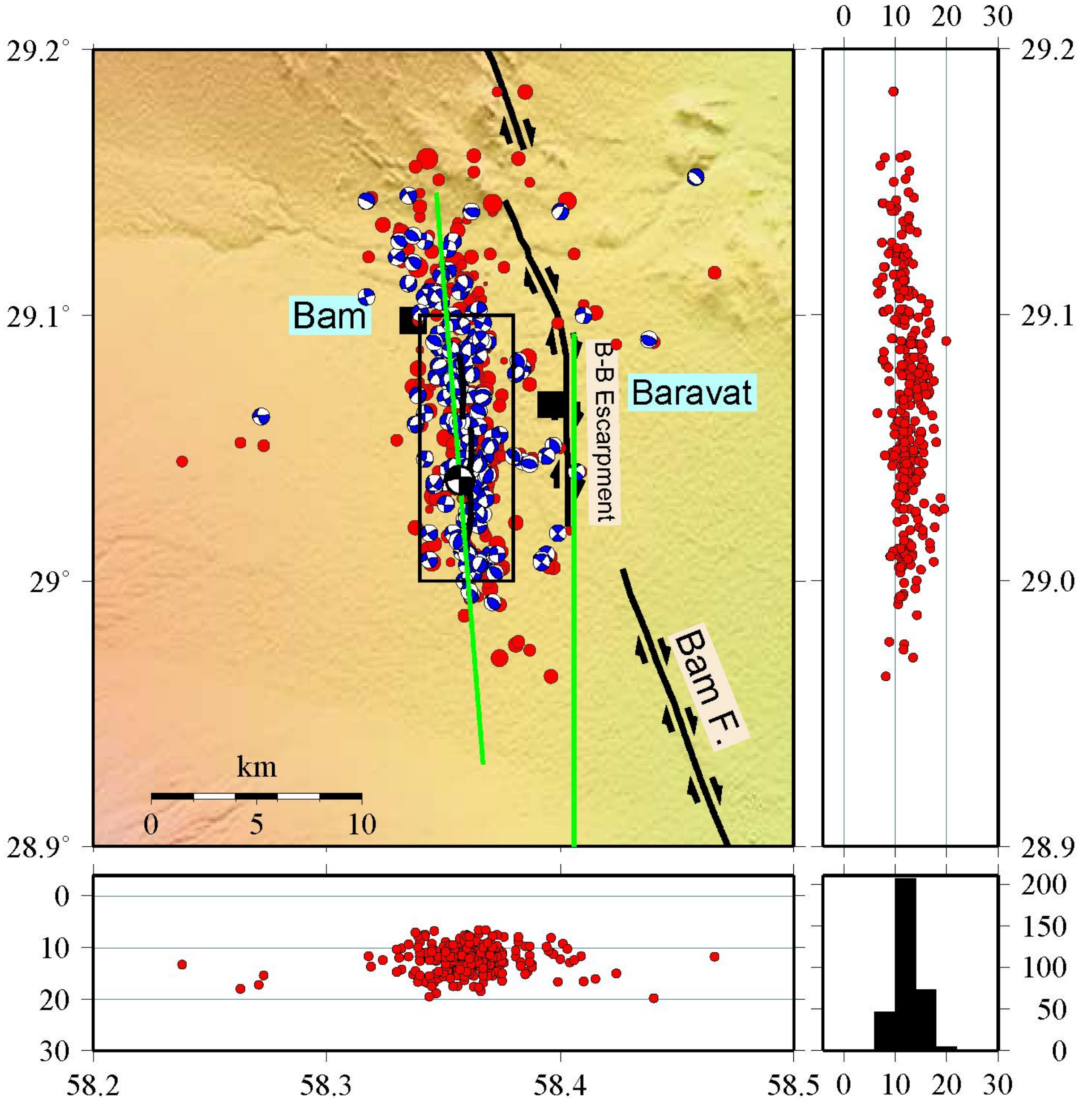


Figure 3. Focal mechanism of the 158 aftershocks of the Bam earthquake by Tatar et al. (2005).

Data

Slip model

Main shock:

- Variable-slip fault model from Funning et al. (2005) that suggest a maximum slip about 2.7 m at a depth of about 6 km

Aftershocks:

- Focal mechanism catalogue from Tatar et al. (2005) by considering a simple rectangular model based on Wells and Coppersmith (1994)

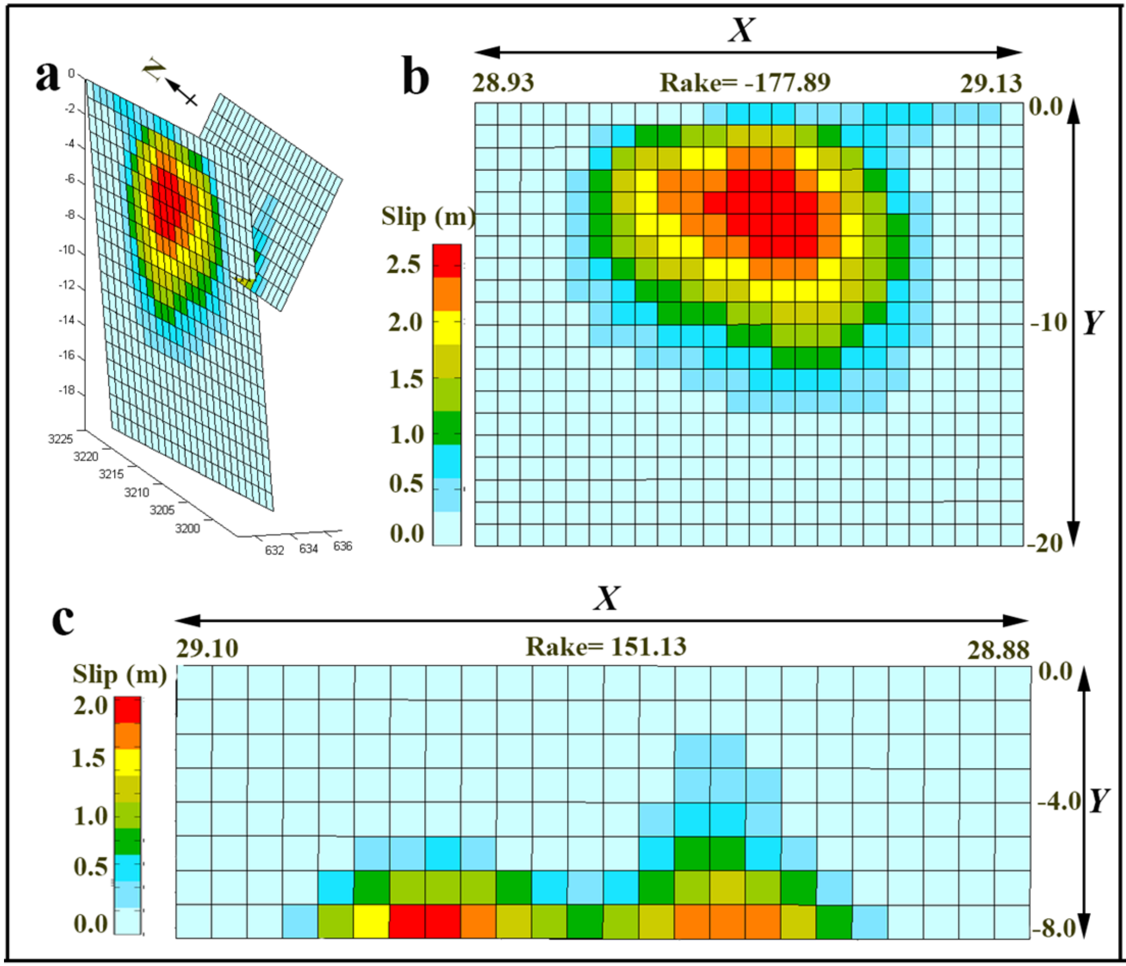


Figure 4. Variable-slip fault model of the Bam earthquake from Funning et al. (2005).

The Coulomb stress triggering hypothesis

Equation of Coulomb stress changes (King et al., 1994)

$$\Delta CFF = \Delta\tau + \mu'\Delta\sigma$$

- Changes in the Coulomb Failure Function
- Changes in Shear Stress
- Effective Friction Coefficient
- Changes in Normal Stress

Most of the previous investigations of Coulomb stress triggering found that static stress change plays an important role in the production of aftershocks and subsequent main shocks on surrounding faults.

Calculation of Coulomb stress changes

- ❖ Young modulus = 8 x 10^5 bar
- ❖ Shear modulus = 3.2 x 10^5 bar
- ❖ Poisson ratio = 0.25
- ❖ Apparent coefficient of friction = 0.4

Coulomb stress changes due to main shock on the nodal plane of aftershocks showed that 77.8% (123 from 158) of aftershocks received positive stress changes from main shock.

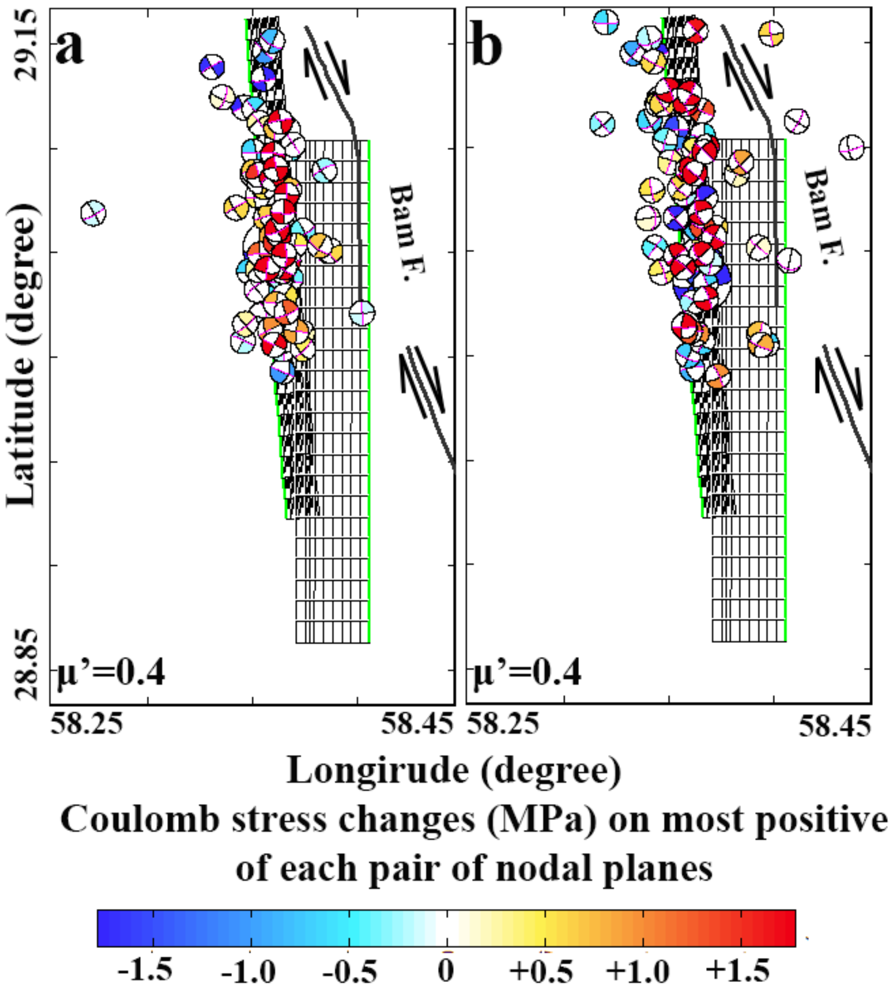


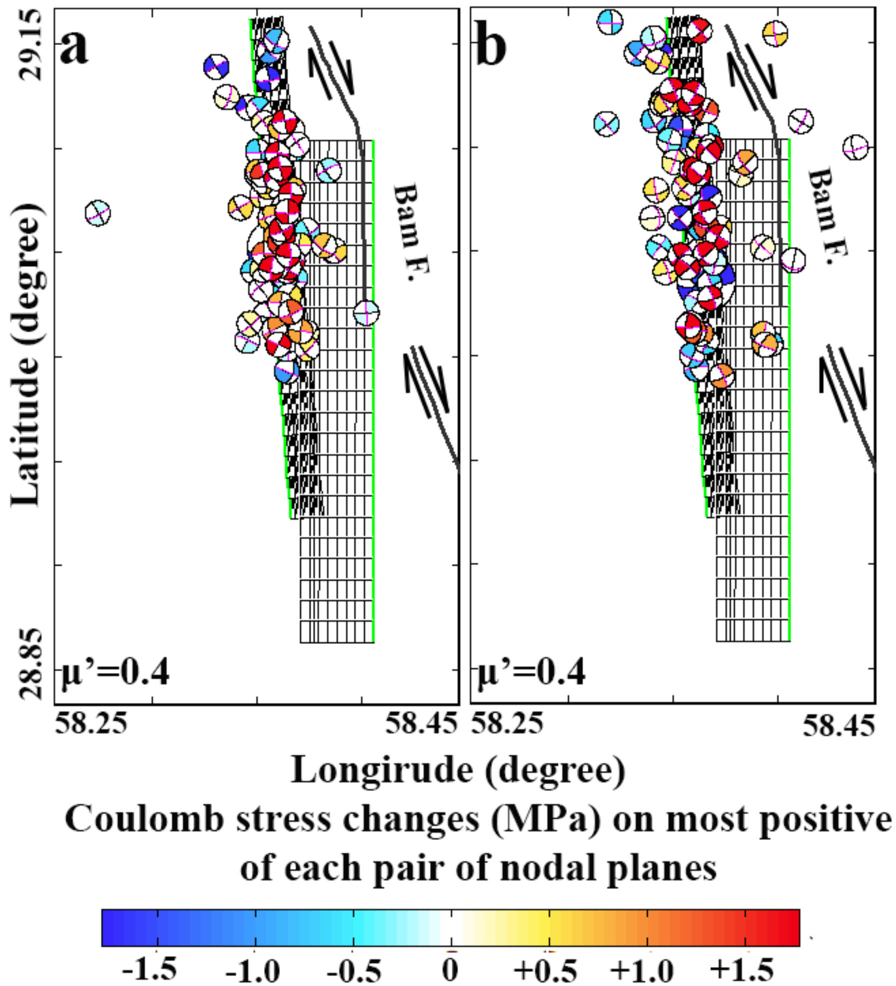
Figure 5. Coulomb stress changes on the nodal plane of the Bam aftershocks. a) Imparted stress on the 81 aftershocks that are put in category A. b) Imparted stress on the 68 and 9 aftershocks that are put in category B and C, respectively.

Calculation of Coulomb stress changes

Coulomb stress changes due to main shock and previous aftershocks on the nodal plane of subsequent aftershock showed that 81.6% (129 from 158) of aftershocks received positive stress changes.

Coulomb index (the fraction of events that received net positive Coulomb stress changes compared to the total number of events) increased from 0.778 to 0.816.

By adding secondary stress, the resolved stress on the 80% of nodal planes of aftershocks increased.



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Conclusion

- **Secondary stress has important role in triggering events.**
- **Aftershocks could trigger the following aftershocks or main shocks.**
- **We should consider secondary stress in forecasting models.**
- **By reducing uncertainties this method will improve.**

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Thanks for your kind attentions