Subsurface seismogenic fault geometry estimated based on faulting mechanics

EGU General Assembly
Vienna | Austria | 7-12 April 2019

EGU 2019-5162

Jiyeon Kim[1], Inho Soh[2] and Chandong Chang[1]* (cchang@cnu.ac.kr)
Department of Geology, Chungnam National University, Daejeon, Korea, Republic Of
K-Water Institute, Daejeon, Korea, Republic Of

1. Objectives

Identifying the geometry of seismogenic faults is the most fundamental aspect in earthquake hazard assessment, which is normally conducted by investigating fault traces exposed to the ground surface.
However, identifying subsurface faults in tectonically stable regions is often difficult, mainly because small-scale faulting activities may not always be exposed to the surface.
The goal of our study is to investigate how much similarity exists in a tectonically stable, and thus slowly deforming region (southeastern part of Korean Peninsula) , between subsurface fault planes deduced from earthquake focal mechanism solutions and surface traces of faults.

We aim to ...

- verify the Quaternary fault planes estimated using the instability method.
- determine subsurface fault planes from focal mechanisms using the method.
- analyze each result of subsurface fault estimation for each stress field estimated using three different inverse methods.
- compare the identified subsurface fault planes to both the fault traces and the orientation of subsurface fault inferred from aftershock distributions.

2. Methodology

- We used the instability method proposed by Vavryčuk(2014) to determine subsurface fault planes from earthquake focal mechanism solutions.
  A value of instability shows how unstable the fault is with respect to the the most unstable and the most stable fault plane and in the given stress field.
  The instability of a fault plane can be evaluated from the stress acting on the fault plane using the reduced stress tensor ($\sigma_1 = 1$, $\sigma_2 = 1 - 2R$, $\sigma_3 = -1$) in the stress field.
  The nodal plane having higher instability value than the other one of a focal mechanism is considered as the fault.

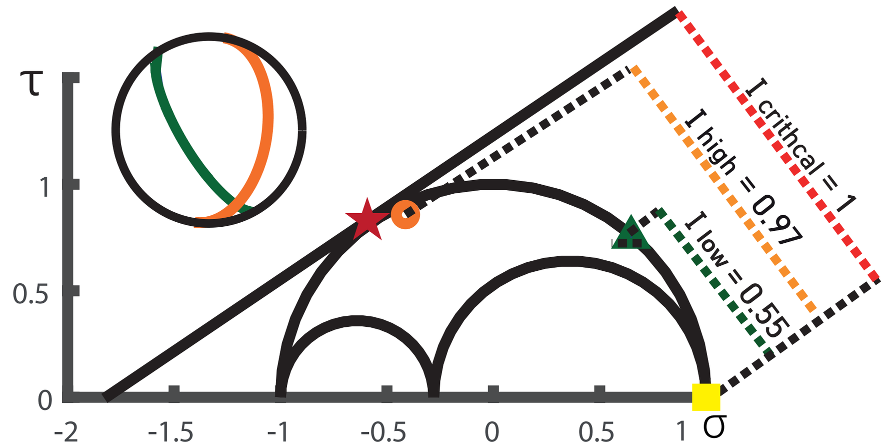


Fig1. *The example for instability estimation of the two nodal planes*

In a certain stress field, the instability vaule of one nodal plane was estimated to be 0.97 and the value of the other nodal was estimated to be 0.55. (The instability value of optimally oriented plane (red) = 1, The most stable one (yellow) = 0 in any stress field). The nodal plane having instability of 0.97 value is determined as the fault.

- IR(Instability Ratio)

$$= \frac{\text{Higher Instability(I) value}}{\text{Lower Instability(I) value}}$$

We additionally identify the ratio of higher I value to lower I value of the nodal planes as an instability ratio to investigate sensitivity to changes in the stress field.

3. Study Area

- The southeastern part of Korean Peninsula is located at eastern edge of the Eurasian plate, away from the plate boundary, and thus is seismically characterized by relatively low magnitude earthquakes (M<5), although two main events (2016 M5.8 Gyeongju and 2017 M5.4 Pohang) occured recently.
  There are a family of major faults in NNE strikes, some segments of which were activated in Quaternary time.

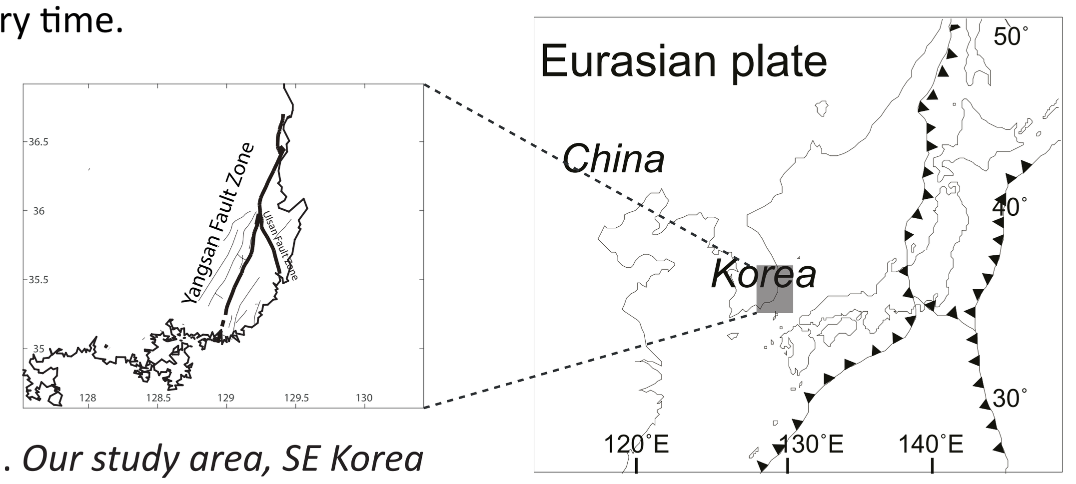


Fig2. *Our study area, SE Korea*

4. Application to Quaternary Fault Data

To validate the shear instability method, we first apply the method to known Quaternary faults in the study area. The method predicts 73% of the Quaternary faults correctly.

We...

1. Collected the Quaternary fault data, including strike, dip, rake(straie), location and age, in our study area, Southeast Korean Peninsula.
2. Inverted stress from the collected fault data.

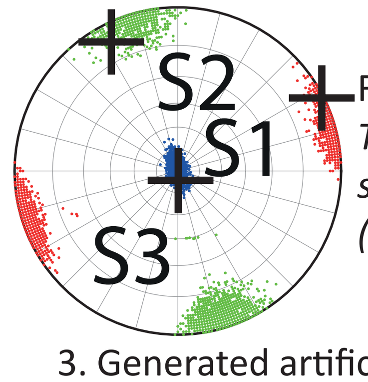


Fig3. (a) *The result of stress inversion (using SATSI)*

3. Generated artifical conjugate fault sets and build data simillar to focal mechanism soiutions by adding conjugate sets to the Quaternary ones.
4. Applied the instability method to the data which is consist of Quaternary and its conjugate fault sets with the inversed stress field

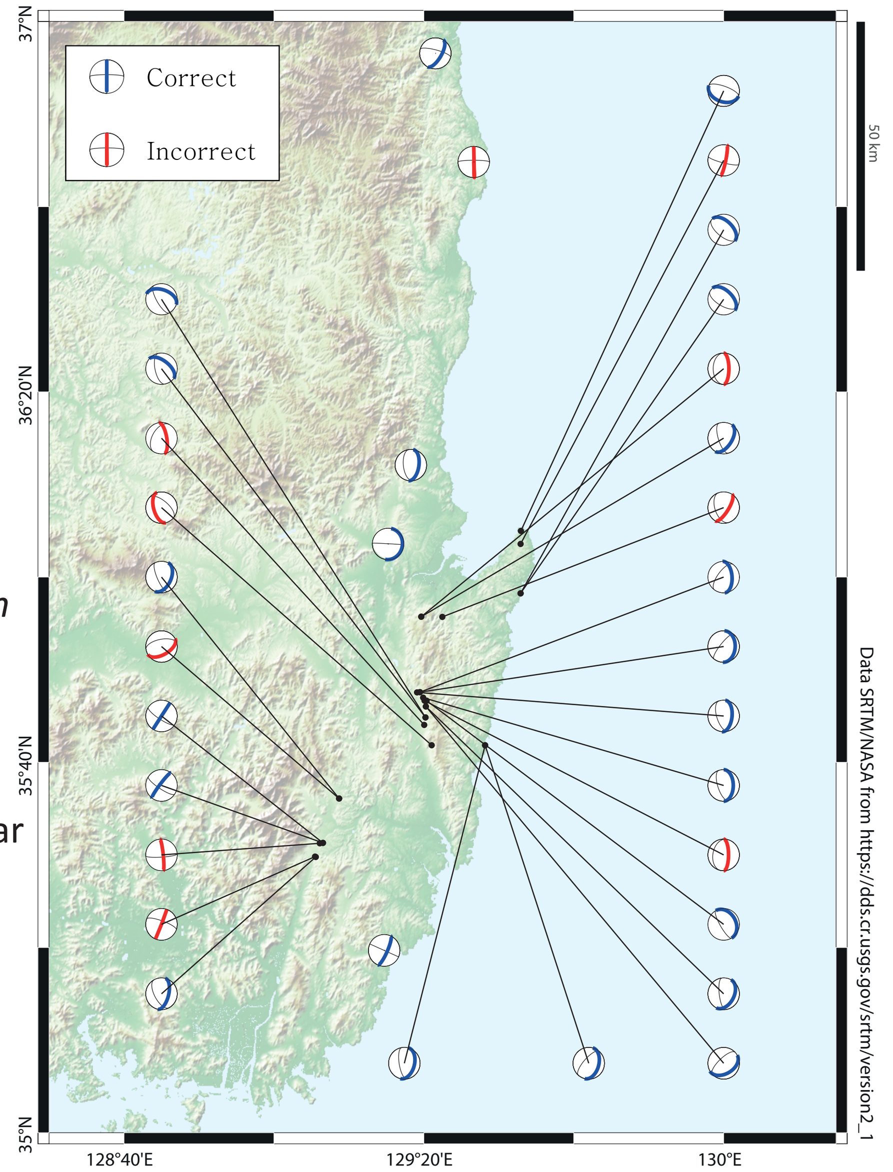
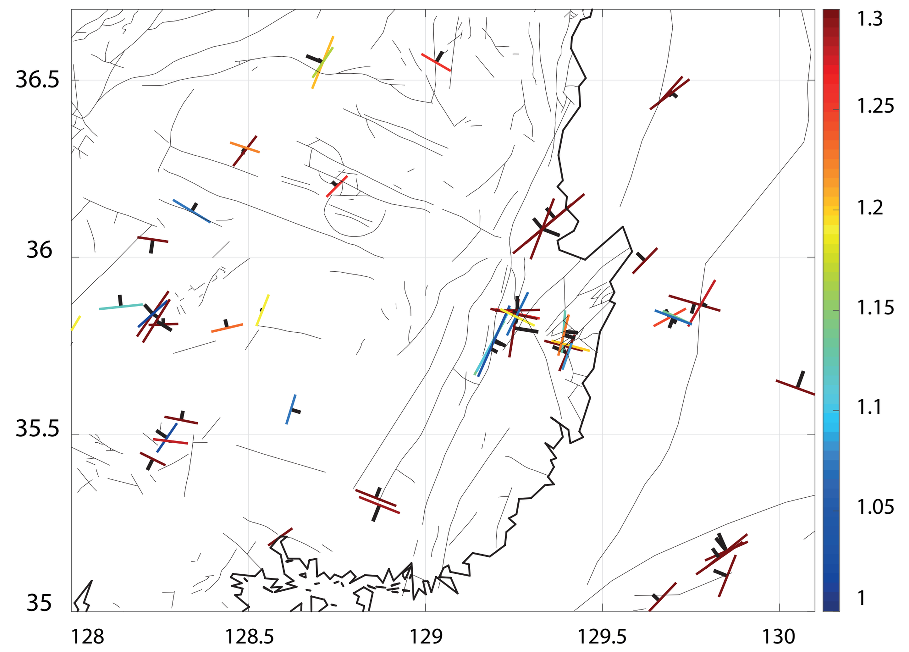


Fig3. (b) The result of the Quaternary fault sets estimation using the instability method

5. Application to Focal Mechanism Solutions (FMS)

We inverted stress from the collected focal mechanism in our study field using misfit and instability inverse method. Apply the method to the FMS data. All parameters except for some ones related to stress, are the same with each other, in order to figure out only effect of changes in the tectonic stress field.



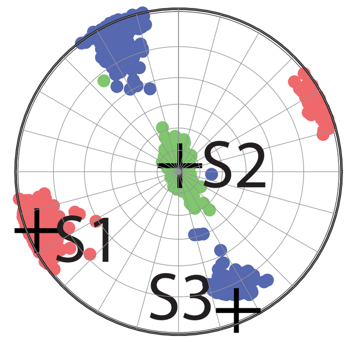
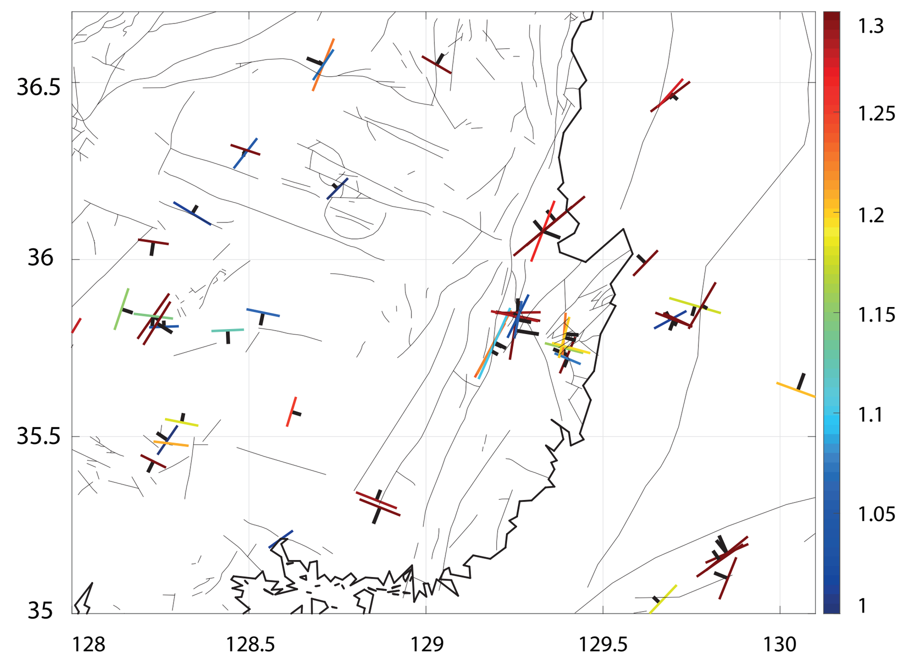


Fig4.
(a) (left) The estimate of subsurface fault planes
(b) (right) in the given the stress field inverted using misfit method (Soh et al., 2018, GJI)



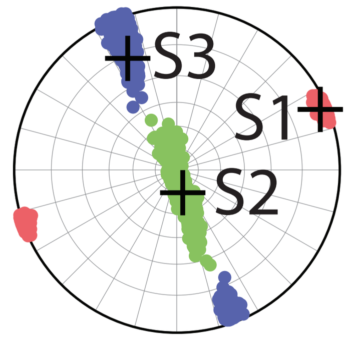
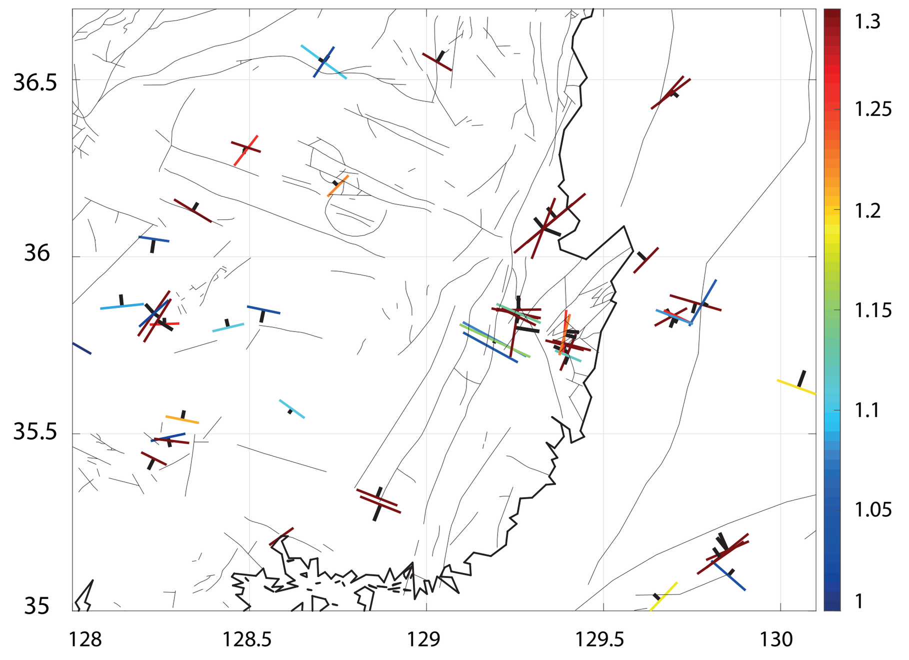


Fig5.
(a) (left) The estimate of subsurface fault planes
(b) (right) in the given the stress field estimated using instability method (Soh et al., 2018, GJI)



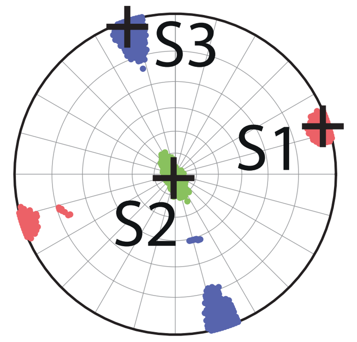


Fig6.
(a) (left) The estimate of subsurface fault planes
(b) (right) in the given the stress field inverted using misfit method (54 FMS with two nodal planes)

The colored lines of the fault strike indicate IR (Instability Ratio) values of that fault.
The black short lines shows the dip directions of each fault.
The black solid lines represent the surface fault trace in our study area.

6. The Result of Subsurface Fault Estimation

- After analyzing the three results of subsurface fault estimation concerning stress fields and IR value, we found:
  - The 81%(44) of fault's orientation is not affected by changes in the stress fields.
  - IR mean value of those fault is about 1.45 (1.50, 1.43, 1.43, respectively) with large standard deviations.
  - The 19%(10) of orientation of fault plane varies with the stress fields, whose mean IR value is 1.10 (1.12, 1.09, 1.08, respectively).
  - There was no change in the fault plane, but the IR value of less than 1.10 was 7%, 16%, 16% of the total (44).
- Comparison the estimated subsurface fault with others
  1. We compared our results to the surface trace map of SE Korean Peninsula, titled Andong and Pusan geological map 1:250:000 (1996, 1998), made by KIGAM (Korea Institude of Geoscience And Mineral Resources) (Black solid lines)
     : Only 44% of estimated subsurface fault orientations are congruent with the surface fault traces.

	Misfit	Instability	Misfit (2 nodal planes)
compatible	44%(24)	44%(24)	43%(23)
incompatible	56%(30)	56%(30)	57%(31)

  2. Compared to the subsurface fault, whose orientations are known independently from associated aftershocks.
     : They are consistent with the orientations of seismogenic faults inferred by distribution of aftershocks.

Gyeongju	Aftershocks	Misfit	Instability	Misfit (2)
Fault orientation (Strike/Dip)	NE-SW/SE	24/78	24/78	24/78
O/X		O	O	O

Pohang	Aftershocks	Misfit	Instability	Misfit (2)
Fault orientation (Strike/Dip)	NE-SW/NW	230/69	230/69	230/69
O/X		O	O	O

Conclusion

- Over 70% of the Quaternary faults estimated correctly.
- The subsurface faults are compatible with the subsurface fault orientation derived from aftershock distributions.
- The subsurface faults are not very consistent with the surface traces.
- This result demonstrates that subsurface 3D fault network may be much more complicated than what we can infer from surface 2D projection of the fault system.
- The closer IR value is to 1, the more sensitive it is to the change of stress field.
- The stress inverse method does not have a large effect on the fault plane determination.