Characterizing 2-D slip distributions along plate-suture mega-thrust during earthquake cycle: a case of the Chihshang fault in eastern Taiwan

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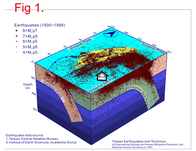
Goal:

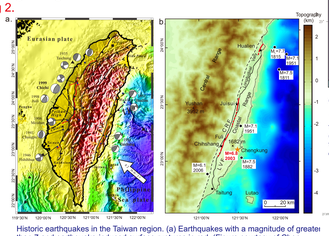
To characterize the change of slip during earthquake cycle along the Chihshang Fault, we invert geodetic data for fault slip during an interseismic period and also during the co- and post-seismic periods of the Dec. 10, 2003, Chengkung earthquake.

Fig 1.



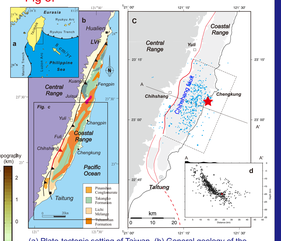
3D Taiwan tectonics and seismicity

Fig 2.



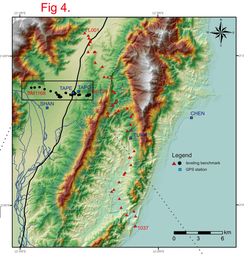
Historic earthquakes in the Taiwan region. (a) Earthquakes with a magnitude of greater than 7 and earthquake-induced surface ruptures in red. (Figure courtesy of Chen Rou-Fei) (b) Earthquakes in eastern Taiwan and 1951 earthquake-induced ground ruptures in red.

Fig 3.



(a) Plate-tectonic setting of Taiwan. (b) General geology of the Coastal Range. The Coastal Range is thrust onto the Longitudinal Valley and the Central Range along the active Longitudinal Valley fault (LVF) (heavy line with triangles pointing in dip direction). (c) Seismicity map of main shock (star) and aftershocks (dots) of the 2003 Mw 6.5 Chengkung earthquake. (d) Cross section of the distribution of the 2003 earthquake sequence.(Lee et al., 2006)

Fig 4.



Leveling benchmarks and GPS stations. Bold solid line is Longitudinal Valley fault (LVF).

Tectonic setting

- Luzon arc of the Philippine Sea plate is colliding with the continental margin of the Eurasian plate(Fig 1).
- Relative convergence of the two plates occurs at a rate of about 80 mm/yr in the direction of 310° (Fig 1 and 2).
- Half the 80 mm/yr of convergence is being taken up on the one neotectonic belt, the Longitudinal Valley in eastern Taiwan considered the plate suture between the two plates.
- The valley is bounded on the east by the Longitudinal Valley fault (LVF) and on the west by the Central Range fault (CRF)
- The LVF is, in particular, highly active, with about 30% of earthquakes per year in Taiwan occurring on or near the fault (Fig 1).

Chihshang fault

- South-central segment of the LVF (Fig 3).
- Approximate 35 km long classified as an active fault of the first category by Central Geological Survey of Taiwan.
- A listric shape and its dip angle decreases from 65º at depth of 5 km to 15º at depth of 20 km (More details shown in Fig 7).
- Reactivated in 1951 (Fig 2)and on Dec. 10, 2003, Chengkung earthquake (Fig 3c).
- Lichi mélange in its hanging wall and thick Holocene alluvial sediments in its foot wall (Fig 3b).
- Subsequently underwent continuous surface creep.

Data acquisition

The **two sets of leveling data** for **semi-co** and **semi-post seismic** vertical displacements (Fig 5) of Cheng-Kung EQ were collected from **three leveling surveys**. Their starting days are **June 20th of 2003**, **December 15th of 2003** and December **20th of 2004**, respectively. Each survey took approximately two weeks.

The another set of leveling data for the interseismic period were collected once per year from **Oct. 2007 to Oct. 2011**. This four-years averaged vertical velocity is shown in Fig 6. There are **five continuous GPS** stations (shown in Fig 4) in this study area installed before 2003. Their daily solutions are shown in Fig 11.

Fig 7.

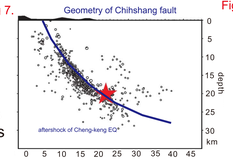
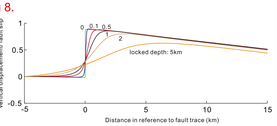


Fig 8.



Deformation on the ground surface for different locked depths. Geometry of modelled fault used is shown in Fig 7.

Adjustments

Based on the observations (Fig 5) and theoretical results of 2D dislocation for different shallow locked depths (Fig 8), we derive co-seismic vertical displacement by the mean as shown in Fig 9. Then, we add the differences between semi-co seismic and new derived co-seimic displacements into the semi-post seismic displacement to gain one-year-long post-seismic displacement. Fig 10 shows all the data sets used in this study. The new derived set of post-seismic vertical displacements is shown in Fig 10e.

Fig 9.

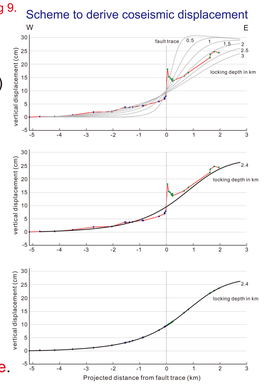


Fig 10.

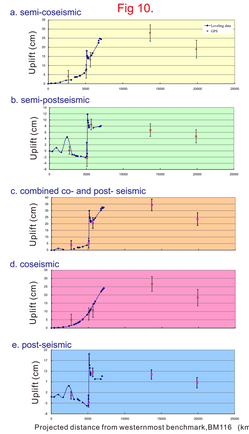
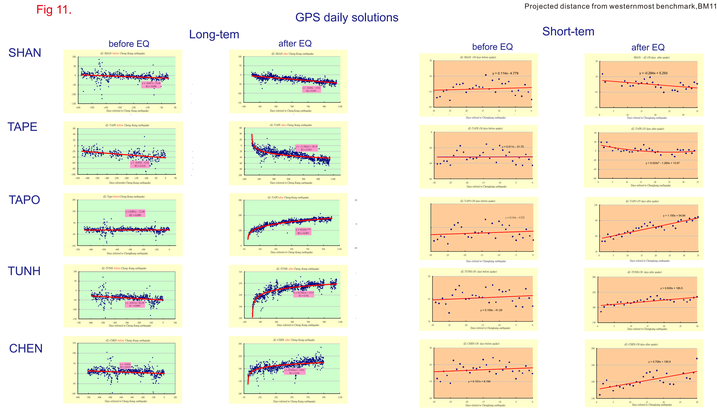


Fig 11.

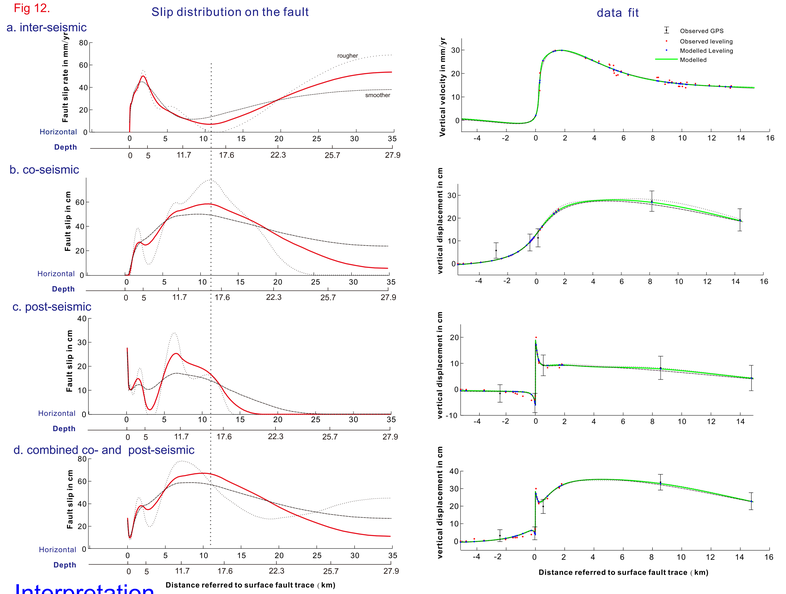


Main findings

We invert the geodetic data to attain the fault slip through a model of 2D dislocation in an elastic half space. Our findings are listed as follows:

- i.The derived maximum 2003 co-seismic fault slip is about 60 cm located at the depth 15 km (Fig 12b).
  ii.The derived locked depth is approximately 1 km.
- i.The post-seismic fault slip shows two-peak type of slip distribution with the shallow peak of slip up to 15 cm at depth of 3-4 km and 25 cm of slip at depth of 10 km (Fig 12c).
  ii.The shallow part of fault slips up to 28 cm near the ground surface.
- i. The 1-year accumulated fault slip shows the derived maximum of 60-70 cm at depth of 7-11 km. 12-17 km (Fig 12d).
  ii. The shallow part of fault slips up to 28 cm near the ground surface as post-seismic.
- The pattern of the slip rate distribution of the inter-seismic periods and the pattern of the sum-up slip of the co- and post- seismic periods are reciprocal at depth greater than 6 km (Fig 12a and 12d).

Fig 12.



Interpretation

- It appears that the tectonic strain in the plate suture at this latitude was mainly accumulated on the Chihshang fault during the inter-seismic period, at depths 6-25 km, which we interpreted as the seismogenic zone.
- The change of slip pattern for the post-seismic might be driven by the EQ induced stress.
- The large misfit on the foot wall for post-seismic might be due to locally non-elastic effect.