



Properties of Low-Frequency Earthquakes Triggered by Large Earthquakes in Southern Taiwan

Department of Earth Science, NCU 10th May, 2013

Chi-Chia Tang

Institute of Earth Sciences, Academia Sinica



⁽Shelly et al., 2007, Nature)

LFEs and Tremor



Why do we study LFEs?

Sciencexpress

Report

Episodic Tremor and Slip on the Cascadia Subduction Zone: The Chatter of Silent Slip



*Tremor activity well corresponded to slip derived from GPS observation.



Garry Rogers* and Herb Dragert

Why do we study LFEs?



*Locations of tremor might reflect fault properties and static and dynamic stresses decaying away from the rupture.

*Tremor and LFEs are extremely stress sensitive and hence could act as a **natural 'stress meter'** to monitor timedependent changes around deep faults, especially before large earthquakes.



(Shelly, 2010, Nature)

Ambient LFEs in Japan

nature

Vol 442|13 July 2006|doi:10.1038/nature04931

LETTERS

Low-frequency earthquakes in Shikoku, Japan, and their relationship to episodic tremor and slip

David R. Shelly¹, Gregory C. Beroza¹, Satoshi Ide² & Sho Nakamula³





Large distant earthquakes with triggering potential

FUNDAMENTAL QUESTIONS:

- 1. Locations of LFE/Tremor in Taiwan
- 2. LFE-generated mechanism







Large distant earthquakes with triggering potential



Detecting LFEs in tremors -- Match filter technique

An example of waveform detection Blue lines: P waves of template Red lines: S waves of template Average Vert. CC = 0.43, Average Horiz. CC = 0.44

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23°36 CF **Detecting LFEs in tremors** 23°24 CHN 23°12 *The locations of LFEs are near a region with relatively high Vp/Vs ratios, suggesting that triggered 23°00 tremor and LFEs reflect possible deep fault slip at the lower crust facilitated by dynamic stresses and 22°48 elevated fluid pressures. CWBSN - 22°36 BATS 120°00' 120°12' 120°24' 120°36' 120°48' 121°00' 121°12' 121°24' 121°36' (a) (c) A' 1000 2000 3000 4000 CR CR CLF CLF LV Meters 0 and the second design of the Depth(km) Depth(km) 40 40 60 60 40 80 100 120 (Km) 20 80 100 120 (Km) 0 20 60 0 40 60 35 40 45 50 55 60 65 70 75 80 85 Vp (km/s) (d) (b) CR CLF Philippine Sea Eurasian 0 EAST WEST Central R. Coastal R. 20 40 777 Neogene sed. Paleogene sed 60 Pre-Tert, basement X14. Lower crust 60 80 100 120 Oceanic crust 20 40 Aseismic crust (Tang et al., 2010, GRL) Vp/Vs 10 17 18

Significance of detected LFEs

*To examine the statistical significance of detected LFEs during largeamplitude surface waves, we computed a β -statistic value (Aron and Hardebeck, 2009).

$$\beta = \frac{Na - NTa/T}{\sqrt{N(Ta/T)(1 - Ta/T)}}$$

, where Na and N are the number of events in the interested period and total number of events, respectively. Ta and T are the time length of interest and the whole time period.

*For absolute values of $\beta \ge 1.64$, the difference in seismicity rate between the two time periods is significant at 90% confidence level, and for $\beta \ge 2.57$, it is significant at 99% confidence level.

Reoccurring LFEs

*Is LFE able to be re-triggered by large teleseismic events?

Yes.

20041226 Sumatra Mw=9.0 Average vertical CC=0.41, Average horizontal CC=0.42

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Reoccurring LFEs





Locations of reoc

The LFEs were mainly located in a
12 and 36 km in depth near the Ch



(a)

Cumulative LFEs

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50

100

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Time (hour)

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..... Time (s)

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-5000

2

5000

10000

4

15000 20000

6



Triggering potential – Amplitude/Peak ground velocity (PGV)



- For all nine triggering earthquakes, the measured transverse PGV ranges from 0.10 cm/s to 0.835 cm/s, which corresponds to the peak dynamic stress of 7.8–61.1 Kpa.
- The PGV of 0.1 cm/s appears to separate most of triggering and non-triggering earthquakes in both transverse and vertical components, which corresponds to an apparent tremor-triggering threshold 7-8 Kpa.

Triggering potential – Incidence angle



- There is no model which is consistent with all observations.
- Low-to-median dipping angle of left-lateral strike-slip fault model could better explains the observations.

Triggering potential – Frequency



- Intermediate-period (30-10 s) surface waves could trigger/modulate tremor/LFE and longperiod signals are not always needed.
- The apparent associations between the triggered tremor and intermediate-period surface waves could also be explained by the amplitude difference in different frequency bands.



Conclusions

- Triggered tremor consist of many LFEs.
- LFEs could be re-triggered by large distant earthquakes.
- The LFEs were mainly located in a compact region between 12 and 36 km in depth near the Chaochou-Lishan Fault.
- The LFE rates do not follow an Omori's type decay, but rather abruptly return to the background rate immediately after the surface-wave passage.

Conclusions

- The locations of LFEs are close to a region with relatively high Vp/Vs ratios.
- Apparent triggering threshold of LFE/tremor are ~0.1 cm/s, or 7–8 Kpa.
- Low-to-median dipping angle of left-lateral strikeslip fault is a better explanation for triggering.
- Intermediate-period (30-10 s) surface waves could trigger/modulate tremor/LFE and long-period signals are not always needed.

What else can the match filter technique do?







Thank you for coming.