Identification of High Frequency pulse from Earthquake asperities along Chilean subduction zone using strong motion

S. Ruiz[1,2], E. Kausel[1], J. Campos[1], R. Saragoni[1] and R. Madariaga[2].

[1] University of Chile, Santiago, Chile.

[2] Ecole Normale Superieure, Paris, France.

Objective

- Correlate high frequency pulse of large interplate Chilean earthquakes with the concept of dominant asperities.

- Identify two or more zones of energy release for this large interplate Chilean earthquakes.

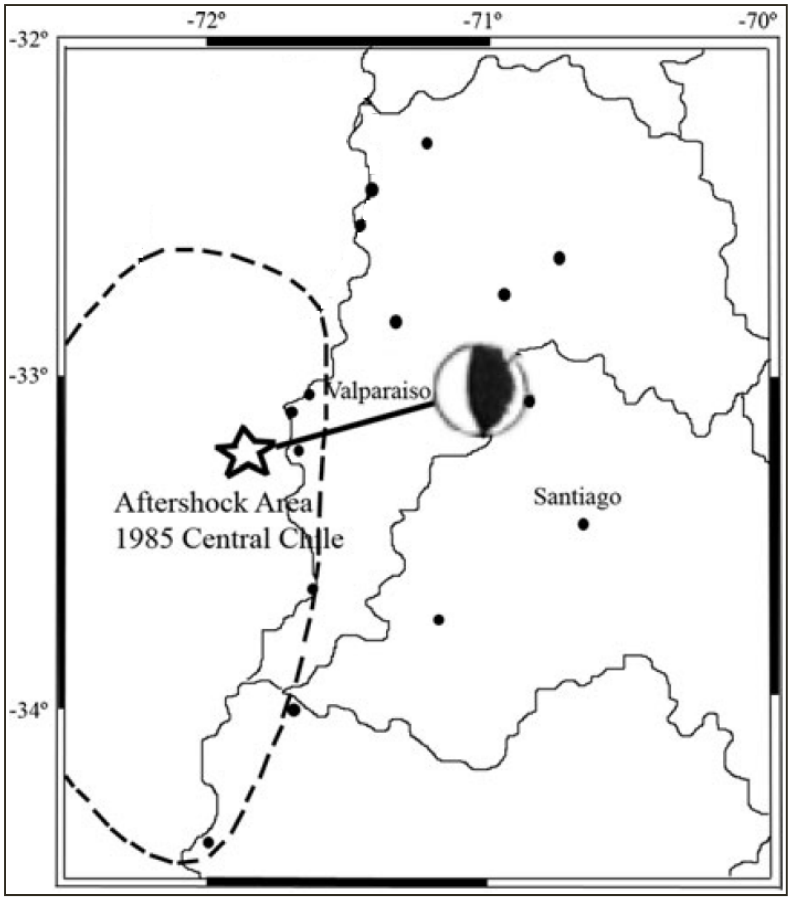
Methodology

- Two large and very well recorded Chilean earthquakes are studied:
  - The Central Chile earthquake of March 3rd 1985 (Mw = 7.8).
  - The Northern Chile earthquake of November 14th 2007 (Mw = 7.7).
- Characterize the high frequency pulses generated by dominant asperities using strong motion data.
- Study the displacements records integrated from the digitized accelerograms.

Definition

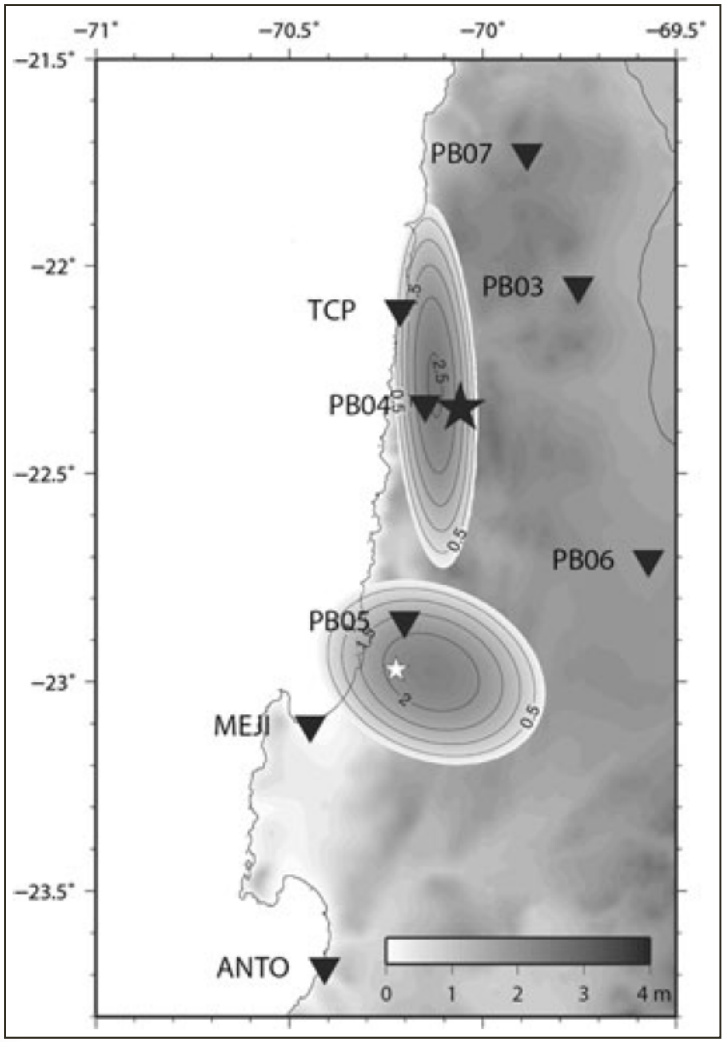
- Dominant asperities: Zones where the principal seismic waves (pulses) are generated.
- This pulses can be identified from the kinematic inversion of earthquakes or directly from strong motion data.

03/03/1985 (Mw = 7.8)



- Epicenter off shore in front of Valparaiso city.
- More than 20 free field accelerograms were recorded at close epicentral distances.
- SMA-1 analog accelerographs.
- Good signal in the range 0.1 – 25 Hz.
- These accelerographs have no common time nor trigger with buffer memory.
- Acausal filter is used.

11/14/2007 (Mw = 7.7)

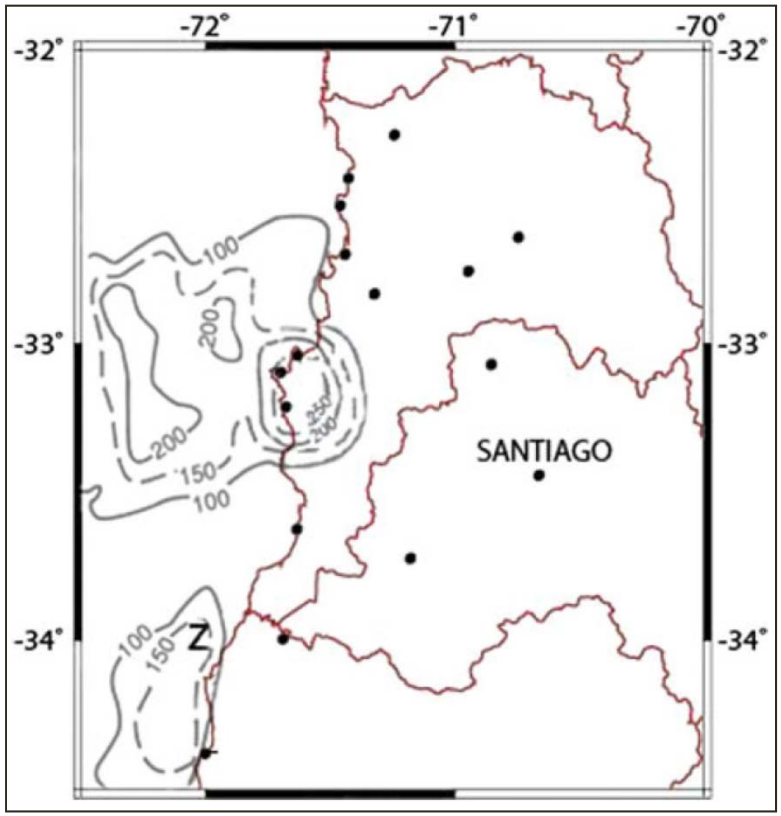


- Hypocenter located at a depth of around 45 km with a continental epicenter.
- More than 20 free field digital accelerograms were recorded at close epicentral distances.
- Good signal in the whole range of frequencies.
- These accelerographs recorded with absolute time.
- Base line corrected and the traces were filtered using a second order lowpass causal Butterworth of cut frequency of 0.08 Hz.

1985 – More than one event

- Christensen and Ruff (1986): Studied P and PP phases.
  - It was composes of two events (first one 16 s before, depth 10 – 40 km).
  - Aftershocks extended 75 km to the North and 125 km to the South of epicenter.
- Monfret and Romanowicz (1986): Studied the Rayleigh waves.
  - Rupture propagate 100 – 150 km to the south or southeast.
- Choy and Dewey (1988): Studied the P + pP + sP wave forms.
  - It was composed of 3 events (first 27 s before and second 17 s before the main shock).
- Mendoza et al. (1994): Studied near-source strong motion.
  - There were 2 principal zones of energy release.

1985 – Relevant aspects

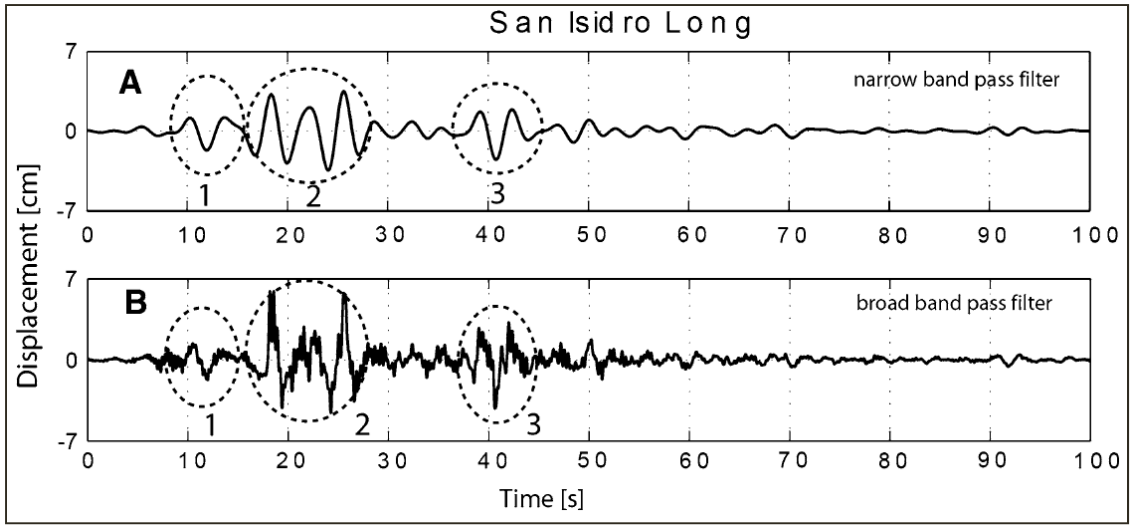


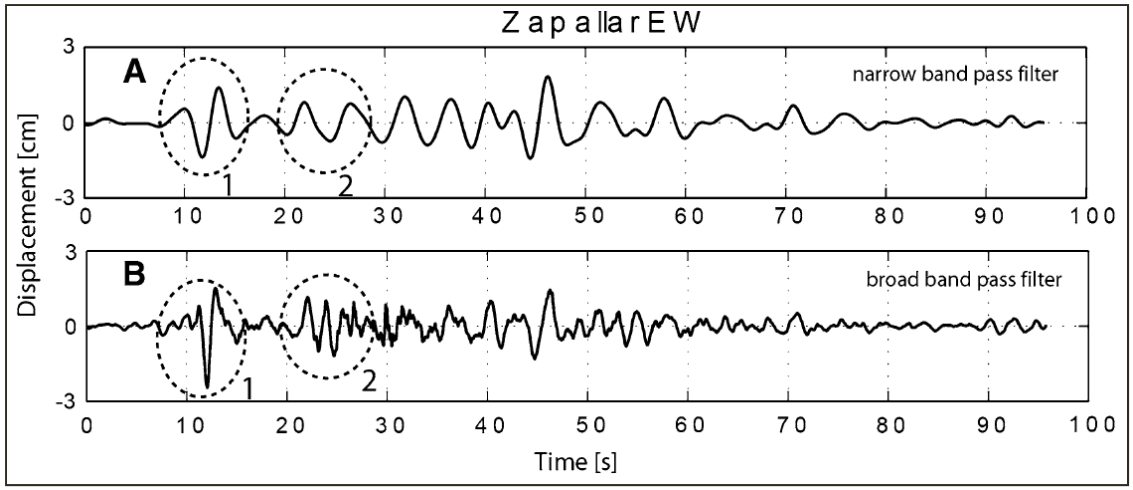
- Valparaiso earthquake had a complex initiation.
- One or more foreshocks.
- At least two large zones of seismic radiation or asperities.
- One near the hypocenter and the other about 50 km to the south.

1985 – Strong motion database

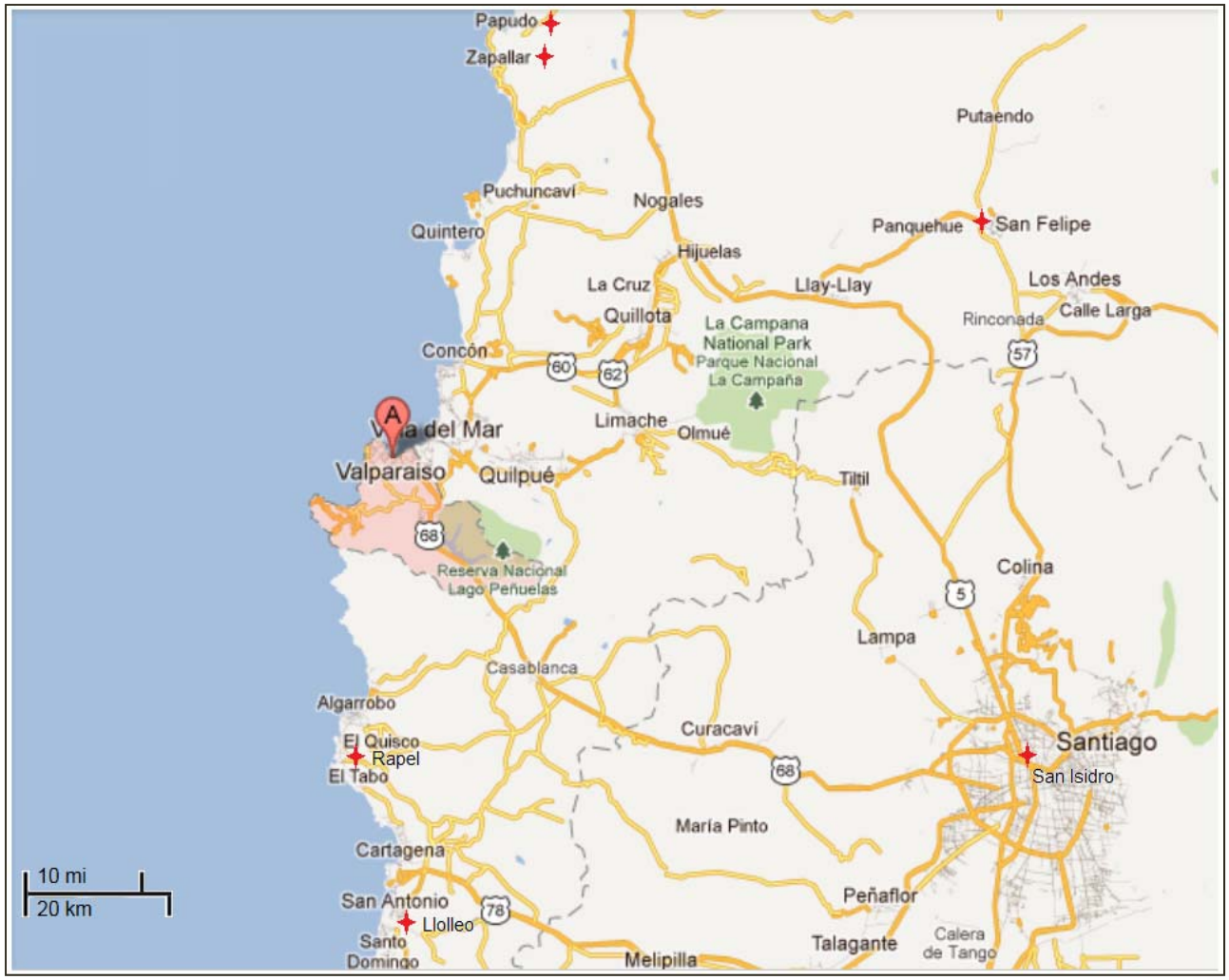
- Records were filtered between 0.1 and 25 Hz.
- This allows to identify pulses associated to the earthquake rupture that apparently were not studied previously.
- Mendoza filtered the strong motion data between 0.133 and 0.5 Hz, but a broader range filter allow to obtain higher frequency characteristics of this earthquake.

1985 – Strong motion database

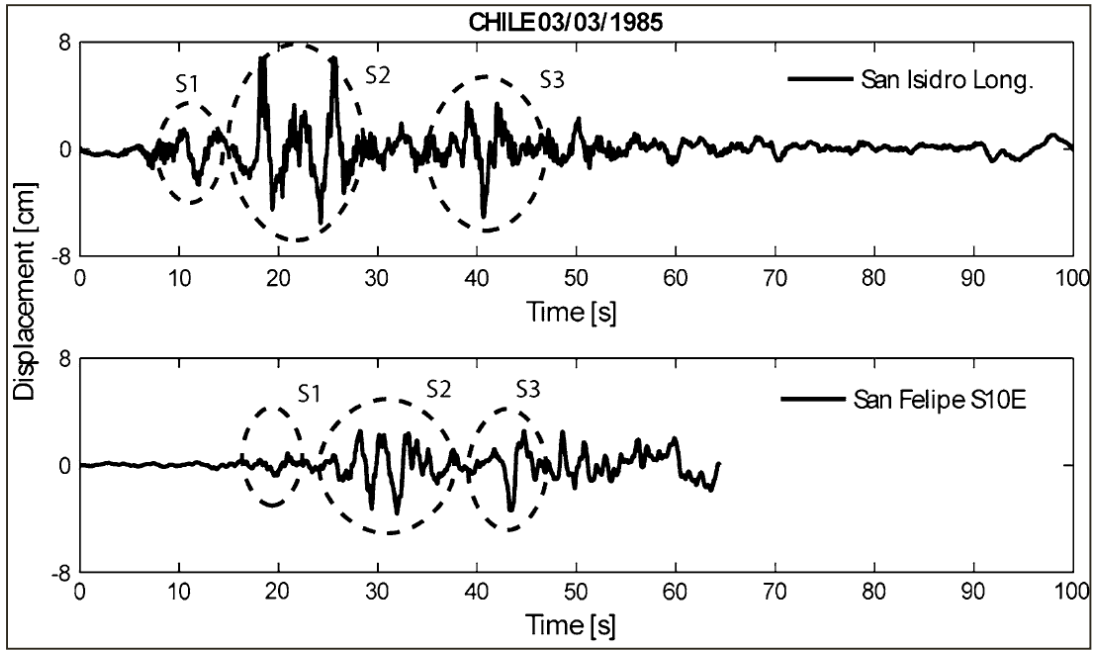




1985 – Strong motion database

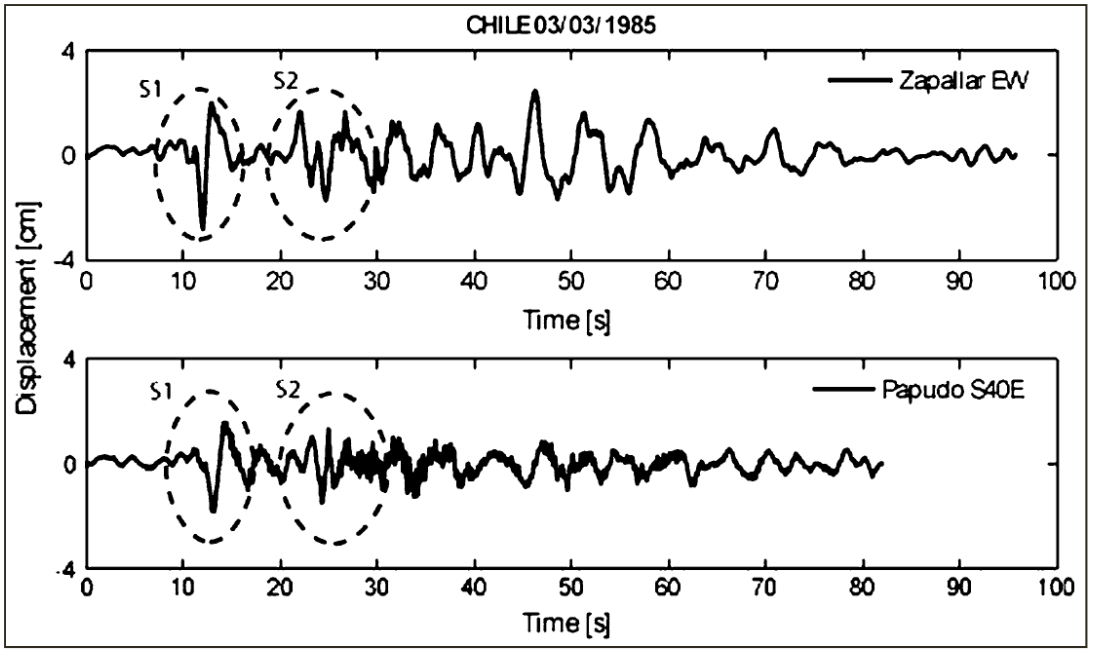


1985 – Strong motion database



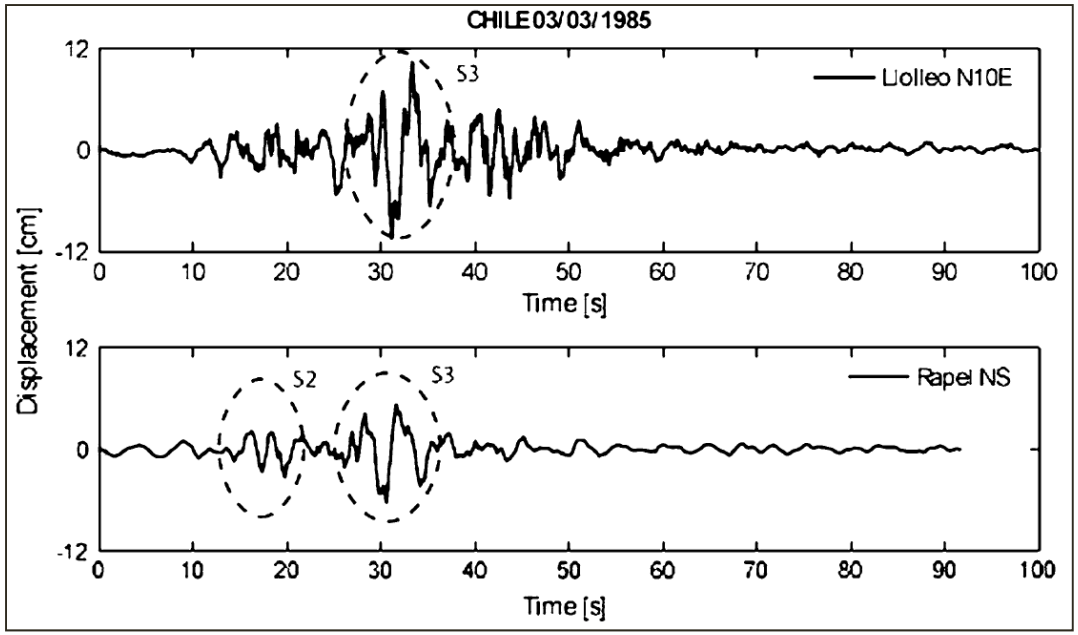
- Located south-east from the epicenter.
- Three main pulses (S1, S2, S3) are evident.
- Pulse S2 is composed of two sub pulses (more complex).
- The traces have not been rotated.

1985 – Strong motion database



- Located to the north of the epicenter.
- Pulse S1 is clearly identified, but pulses S2 and S3 cannot be clearly distinguished.
- Pulse S1 shows a bigger amplitude (coastal records).

1985 – Strong motion database



- Located to the south of epicenter (coastal records).
- Pulse S3 is clearly identified, but pulses S1 and S2 cannot be clearly distinguished.
- Pulse S3 shows a bigger amplitude.

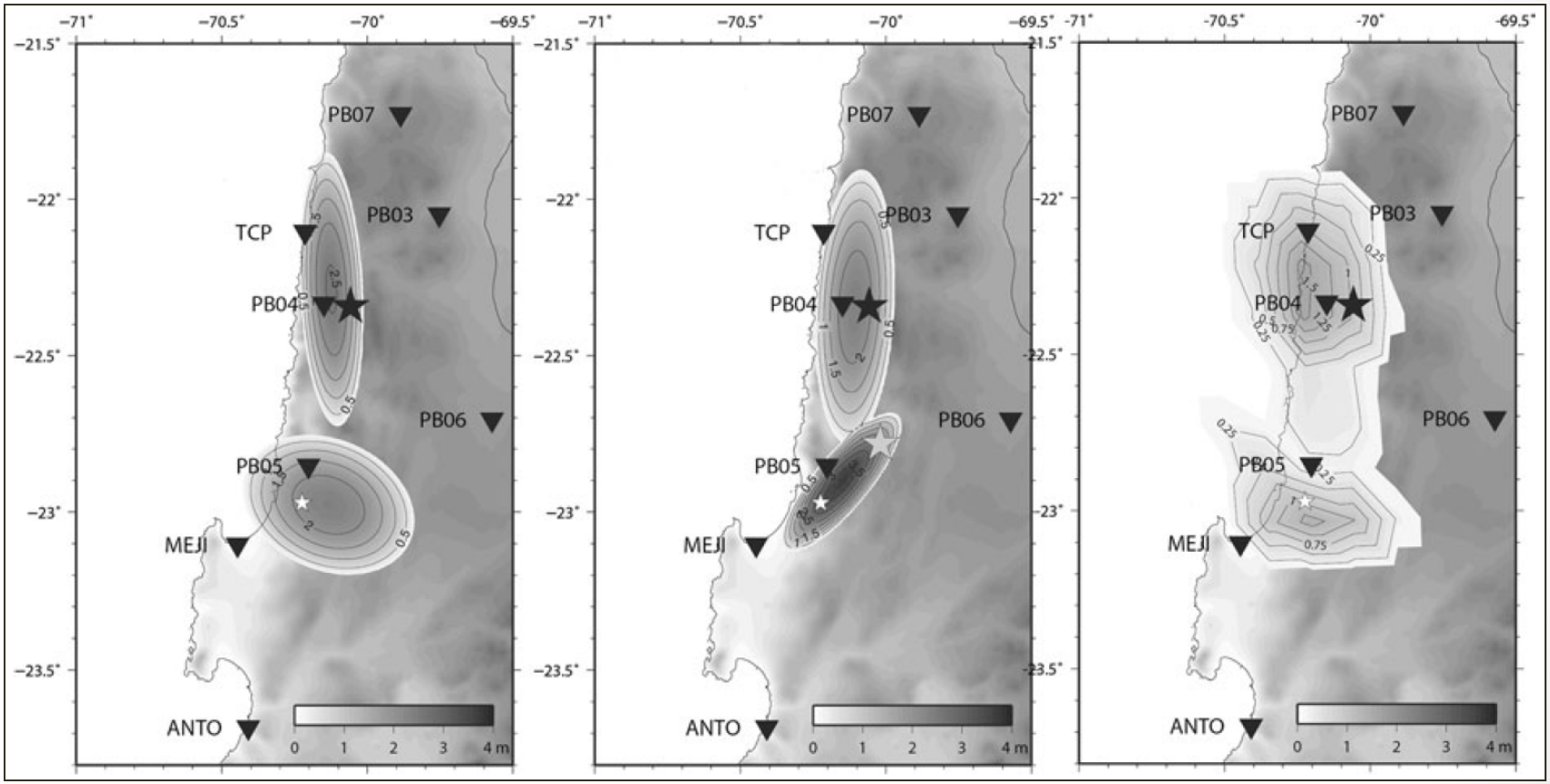
1985 – Conclusions

- The event of 3rd March 1985 is the result of the sum of subevents of smaller magnitudes (difference in the arrivals of each pulse).
- These pulses are not due to soil effects. Llolleo (sand) and Rapel (rock) show almost identical second and third pulses.
- The predominant direction of pulse S3 is NS (stations located to the east of the epicenter show lower amplitude for S3).
- The asperity related with pulse S3 is located to the south of the epicenter (because stations to the north almost don't record this pulse).
- Considering a rupture velocity of 3 km/s and a separation of 10 s between pulses implies distances between dominant asperities of about 30 km (agree with other studies).

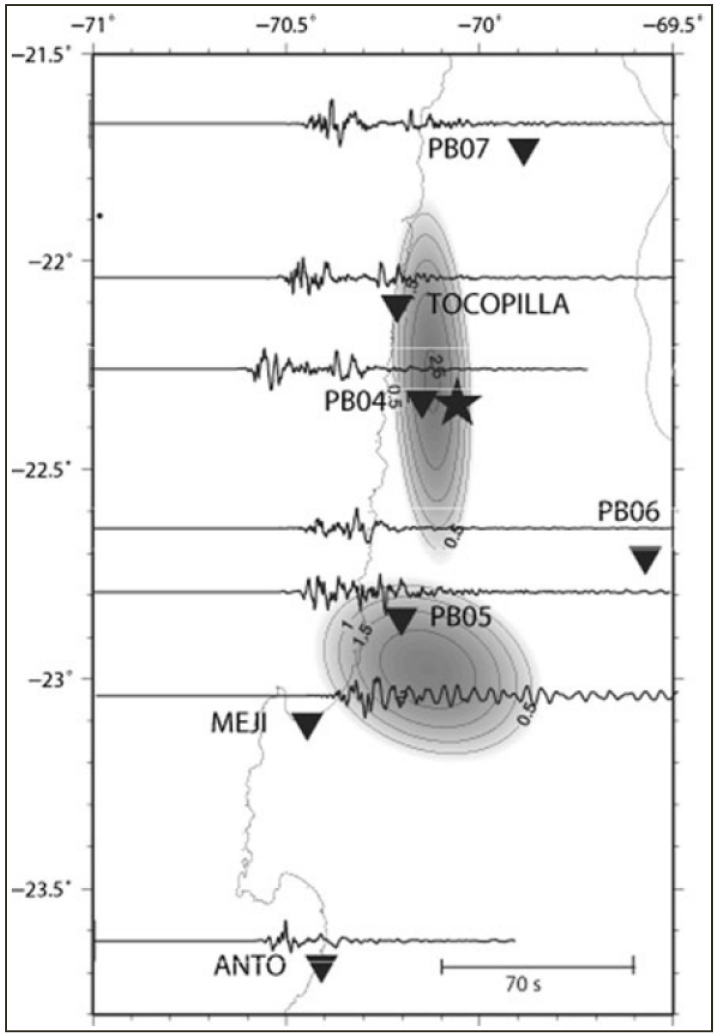
2007 – More than one event

- First and second events were observed directly in the original accelerations records and more clearly in the displacements records (doubly integrated accelerograms).
- Peyrat et al (2009) used a 0.01 – 0.1 Hz bandpass.
  - Observed two pulses in the strong motion records.
- Kinematic inversion models show two well defined zone of energy release, with a second event occurring about 23 s after the main shock in the southern part of the rupture area, at a distance of 49 km, with an azimuth of 175° wrt first event.
- GPS and interferometric data also confirm this fact (Bejar-Pizarro et al., 2008).

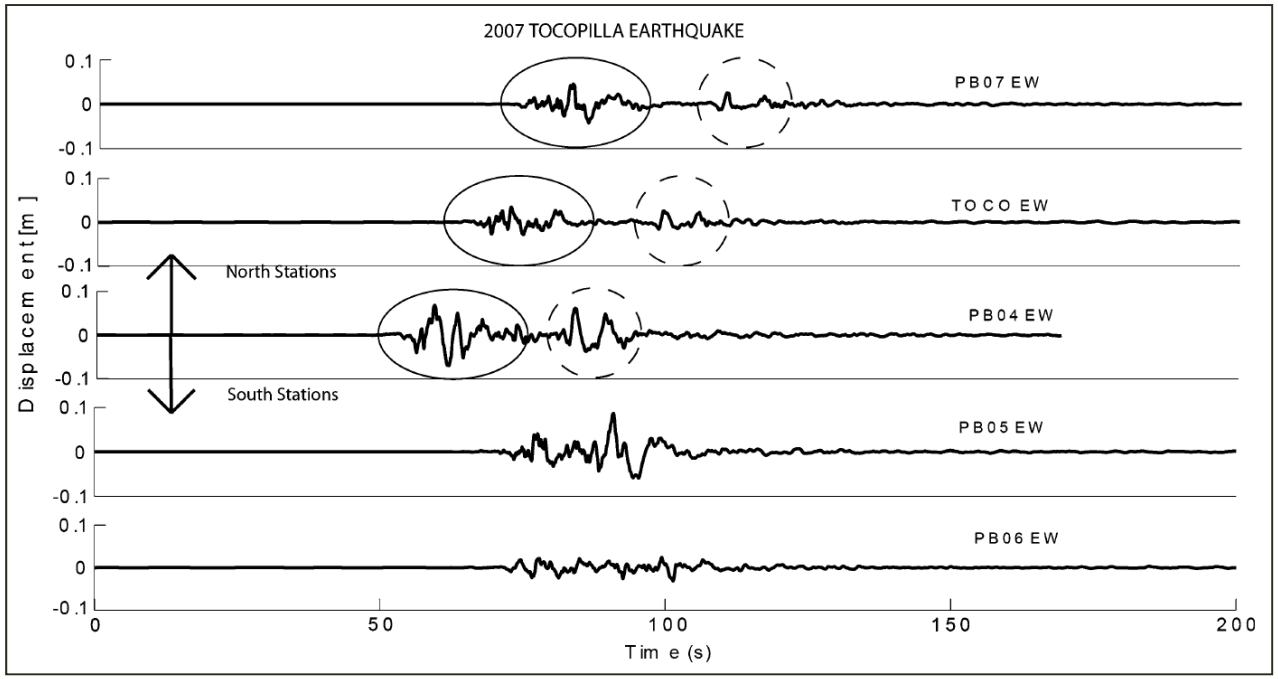
2007 – More than one event



2007 – Strong motion database

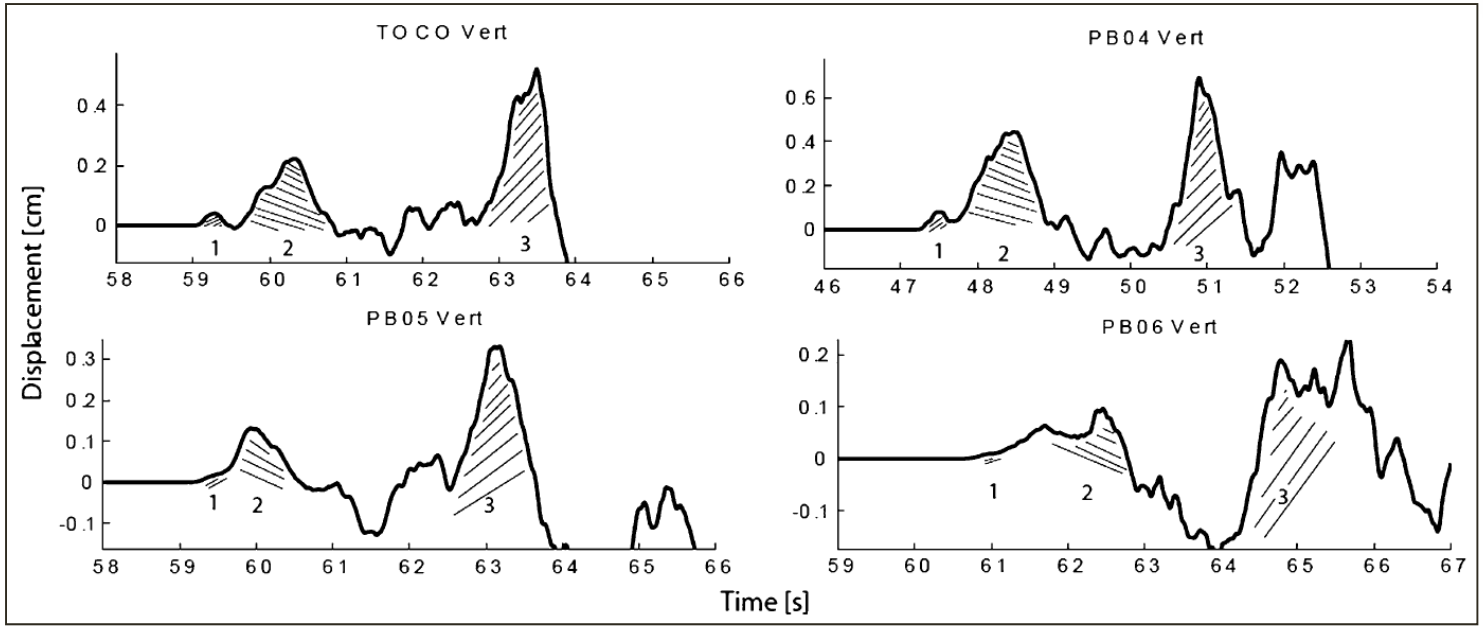


2007 – Strong motion database



- In the northern stations the two arrivals have been identified.
- In the southern stations the two pulses cannot be distinguished.

2007 – Strong motion database



- Analyzing P waves of the vertical component near the epicenter (zoom for early seconds) it is possible to observe 3 similar waves at all stations – 3 subevents.

2007 – Conclusions

- The event of 14th November 2007 is the result of the sum of subevents of smaller magnitudes (difference in the arrivals of each pulse).
- Shape and amplitude of identified pulses are similar to those of the 1985 Central Chile earthquake.
- The direction of rupture propagation is to the south (it is not possible identified the two pulses in the southern stations because the arrival of the two energy pulses is almost simultaneous).
- The asperity related with pulse S3 is located to the south of the epicenter (because stations to the north almost don't record this pulse).
- Considering a rupture velocity of 3 km/s and a separation of 10 s between pulses implies distances between dominant asperities of about 30 km (agree with other studies).