



# The 3<sup>rd</sup> Japan-Peru Workshop on Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru

## DEVELOPMENT OF STRONG MOTION NETWORK IN PERU

Zenón Aguilar Bardales, Dr. Eng.



## G1 GROUP

(Seismic Motion and Geotechnical /  
SMGT Group)

Japanese members:

S. Nakai, (Chiba Univ.)  
T. Sekiguchi, (Chiba Univ.)  
D. Calderon, (Chiba Univ.)  
H. Yamanaka, (Titech)  
H. Arai, (BRI)  
S. Koyama, (BRI)  
N. Pulido, (NIED)

Peruvian members:

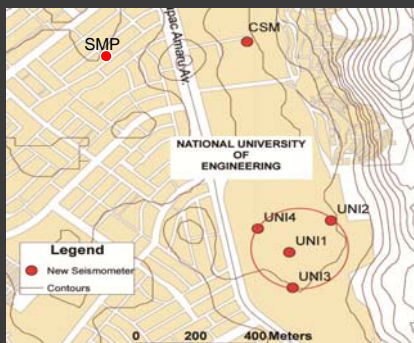
Z. Aguilar, (CISMID)  
F. Lazares, (CISMID)  
S. Alarcón, (CISMID)  
S. Quispe, (CISMID)  
C. Gonzales, (CISMID)  
H. Tavera, (IGP)  
I. Bernal, (IGP)  
D. Portugal, (IGP)

## First Stage:

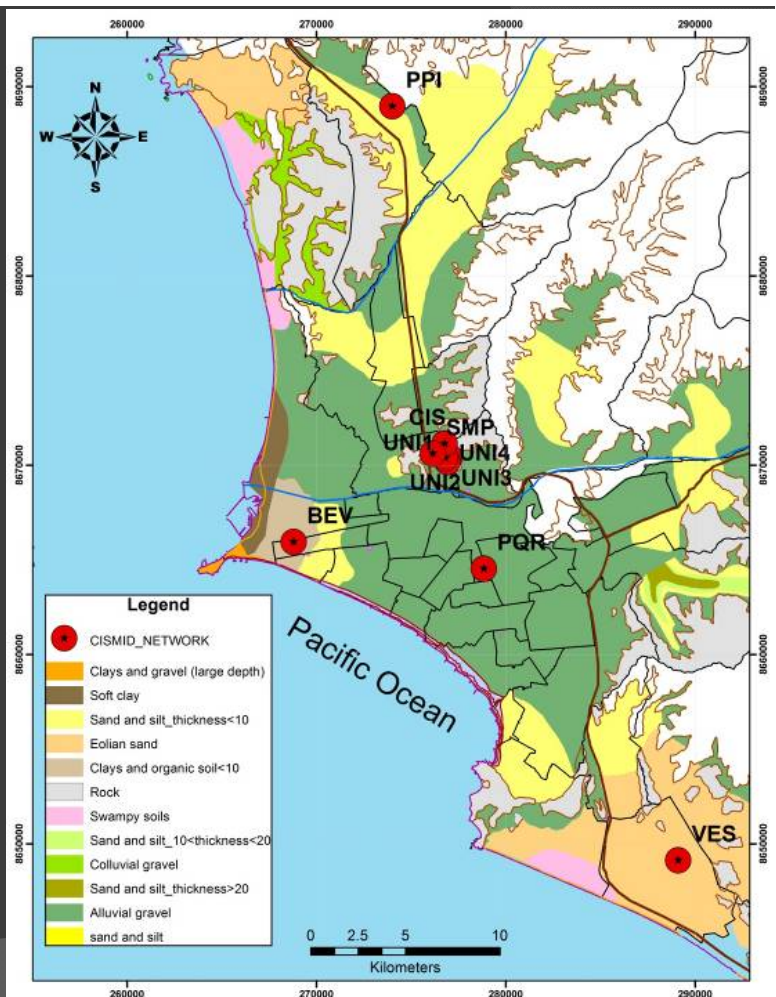
# Implementation of the Seismic Network in Lima City

In the framework of the Project for «Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru», 10 new accelerometers were installed in different places throughout Lima City.

Their seismic records will let us to estimate the soil response at different local site conditions.



Array of Seismometers in UNI







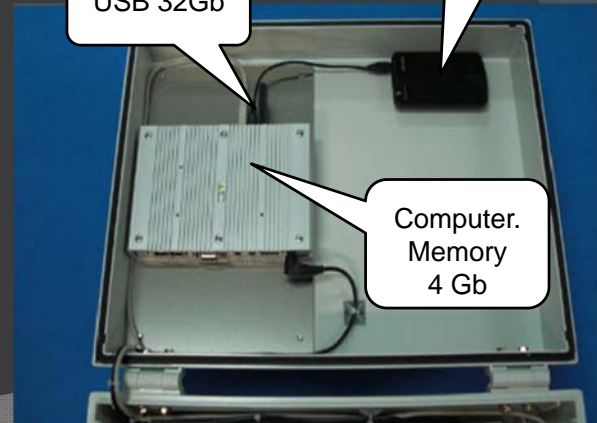
Localization of the battery.  
Time duration: 12 hours

Compact Flash  
2Gb

SSD 120Gb

USB 32Gb

Computer.  
Memory  
4 Gb

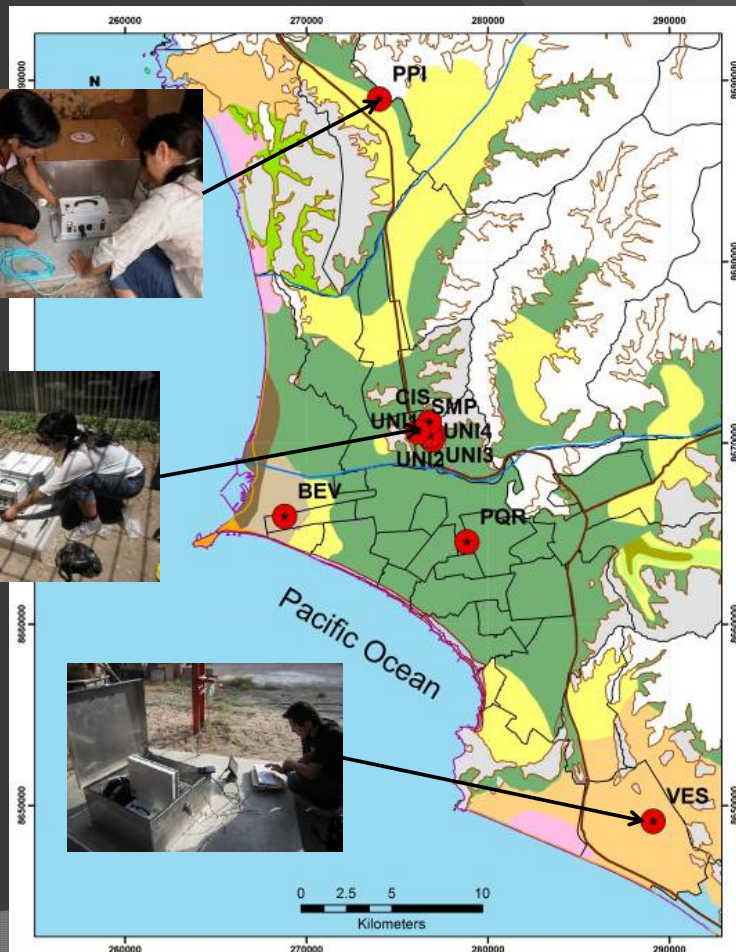


**Accelerometer model:** Tokyo Sokushin Co. Ltd  
CV-374 A2

**Continuous record** : 10 minutes, maximum  
23 days

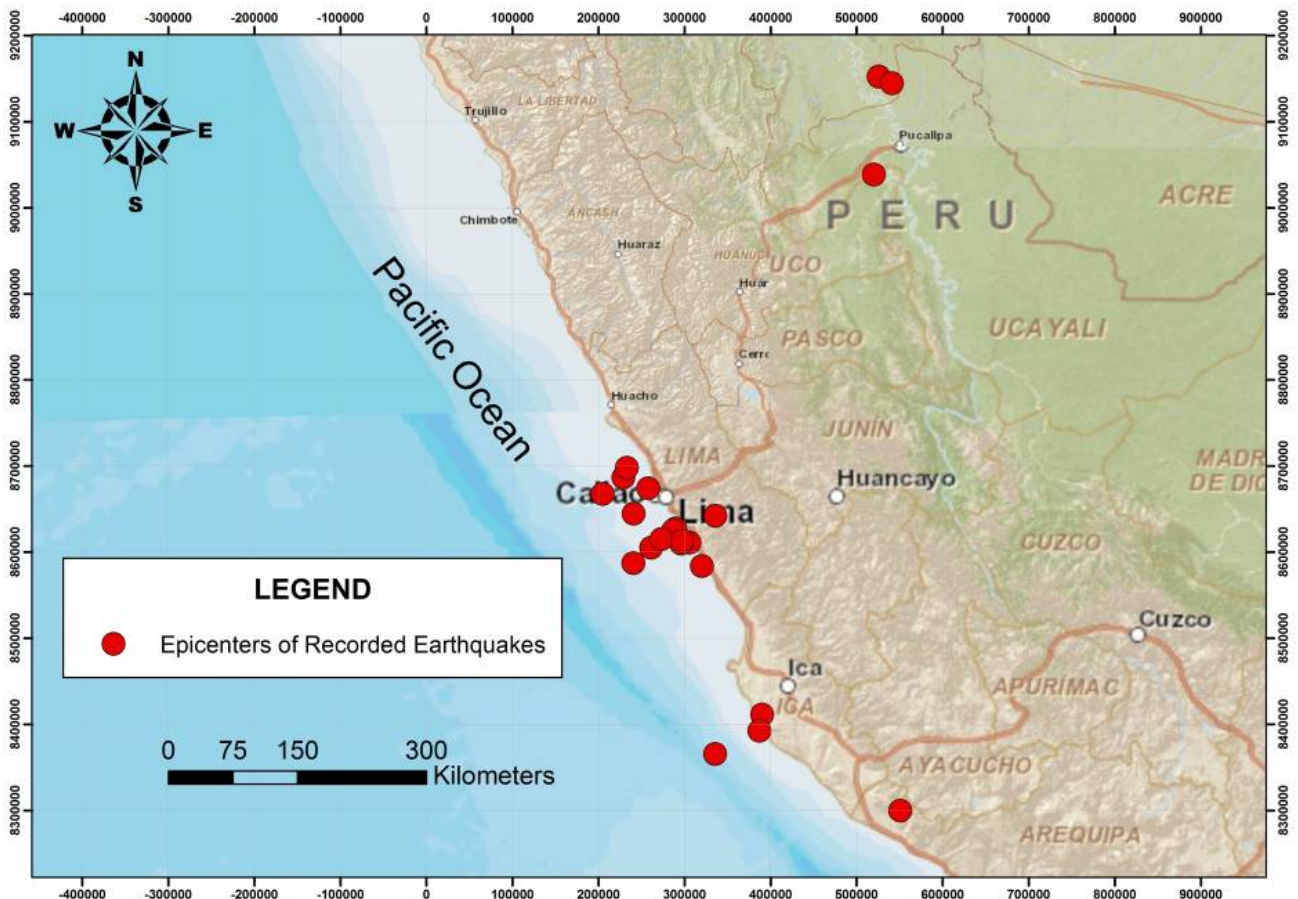
- Storage Units** :
1. Continuous
    - 1.1 Compact Flash
    - 1.2 Computer
  2. Compressed Files at 3:00am
    - 2.1 USB 32Gb
    - 2.2 SSD 120Gb

## Installation of the New Accelerometers



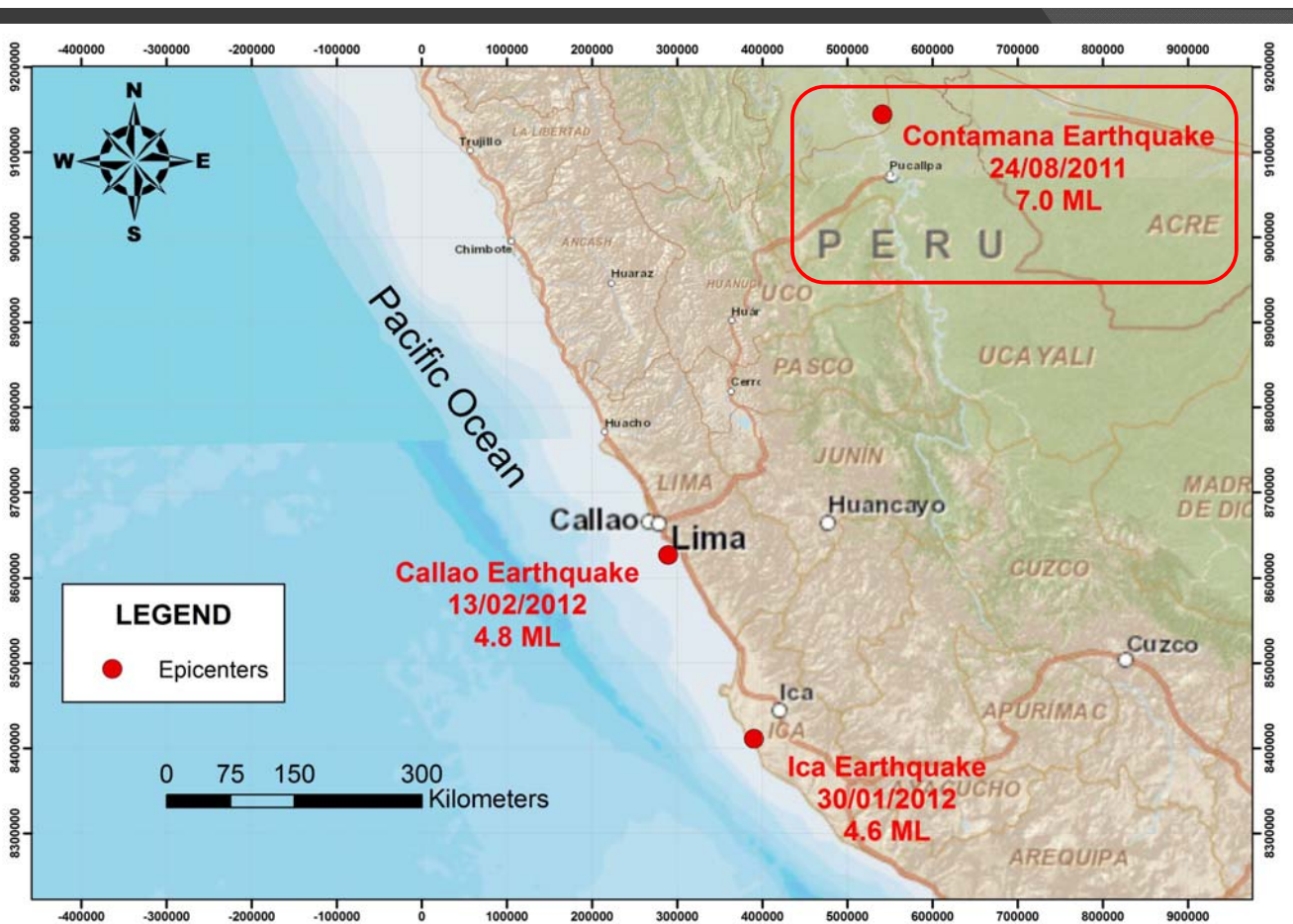
# Summary Table of Recorded Events. CISMID Seismic Network (23 events)

Date	Local Time	Reference	Depth (km)	Magnitude (ML)	CISMID Seismic Stations									
					BEV	CIS	PPI	PQR	SMP	UNI1	UNI2	UNI3	UNI4	VES
<b>2012</b>														
18/02/2012	21:19:23	12 km NW of Callao	47	4.0	OK	X	OK	OK	OK	OK	X	OK	OK	OK
13/02/2012	23:42:20	42 km S of Lima	42	4.8	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
30/01/2012	0:10:58	47 km SW of Cañete	54	6.3	X	OK	X	OK	OK	OK	OK	OK	X	OK
22/01/2012	21:31:13	63 km W of Callao	37	4.4	X	OK	X	OK	OK	X	X	X	X	OK
19/01/2012	15:58:34	61 km S of Callao	48	3.9	OK	OK	OK	OK	OK	OK	X	OK	X	OK
<b>2011</b>														
30/12/2011	4:22:12	83 km SW of Ica	54	5.3	OK	OK	OK	OK	X	OK	OK	OK	OK	X
29/12/2011	8:45:40	63 km SE of Lima	52	4.6	OK	OK	OK	OK	X	OK	OK	OK	X	OK
26/12/2011	15:29:41	43 km NW of Cañete	52	4.4	OK	OK	OK	OK	X	X	OK	OK	OK	OK
19/12/2011	0:37:56	34 km SW of Callao	44	4.7	X	X	OK	OK	X	OK	OK	OK	OK	OK
19/11/2011	22:00:28	37 km WSW of Ancón	56	3.9	X	X	X	X	X	OK	OK	OK	OK	OK
28/10/2011	18:46:00	63 km SW of Ica	35	5.8	X	OK	X	X	X	OK	OK	OK	OK	X
28/10/2011	13:54:25	117 km SW of Ica	30	6.7	X	OK	X	X	X	OK	OK	OK	OK	X
02/10/2011	11:33:12	61 km SSE of Lima	74	4.0	OK	X	X	X	X	X	OK	X	X	X
24/08/2011	12:46:11	44 km SE of Contamaná	149	7.0	OK	OK	X	OK	X	OK	X	OK	OK	OK
01/08/2011	9:30:09	31 km O of Ancón	63	4.0	X	OK	X	X	X	OK	X	OK	OK	X
30/07/2011	9:02:20	90 km SSW of Lima	31	4.1	X	OK	X	X	X	OK	X	OK	OK	X
13/07/2011	5:07:51	45 km S of Lima	54	4.2	X	OK	X	OK	X	X	X	X	X	OK
11/07/2011	10:20:17	54 km S of Lima	54	3.9	X	OK	X	OK	X	X	X	X	X	OK
29/06/2011	0:23:07	35 km NE of Chilca	21	3.7	X	X	X	X	X	OK	X	X	X	X
26/06/2011	6:45:50	14 km WSW of Chilca	49	4.0	X	OK	X	X	X	OK	X	X	X	X
04/06/2011	8:37:42	60 km SE of Contamaná	141	5.0	X	OK	X	X	X	OK	OK	OK	OK	X
07/05/2011	5:33:44	9 km ENE of Acaiacute	80	5.0	X	OK	X	OK	X	X	OK	OK	OK	OK
27/03/2011	8:26:36	48 km SE of Curimana	146	5.2	X	X	X	X	X	OK	X	OK	X	X

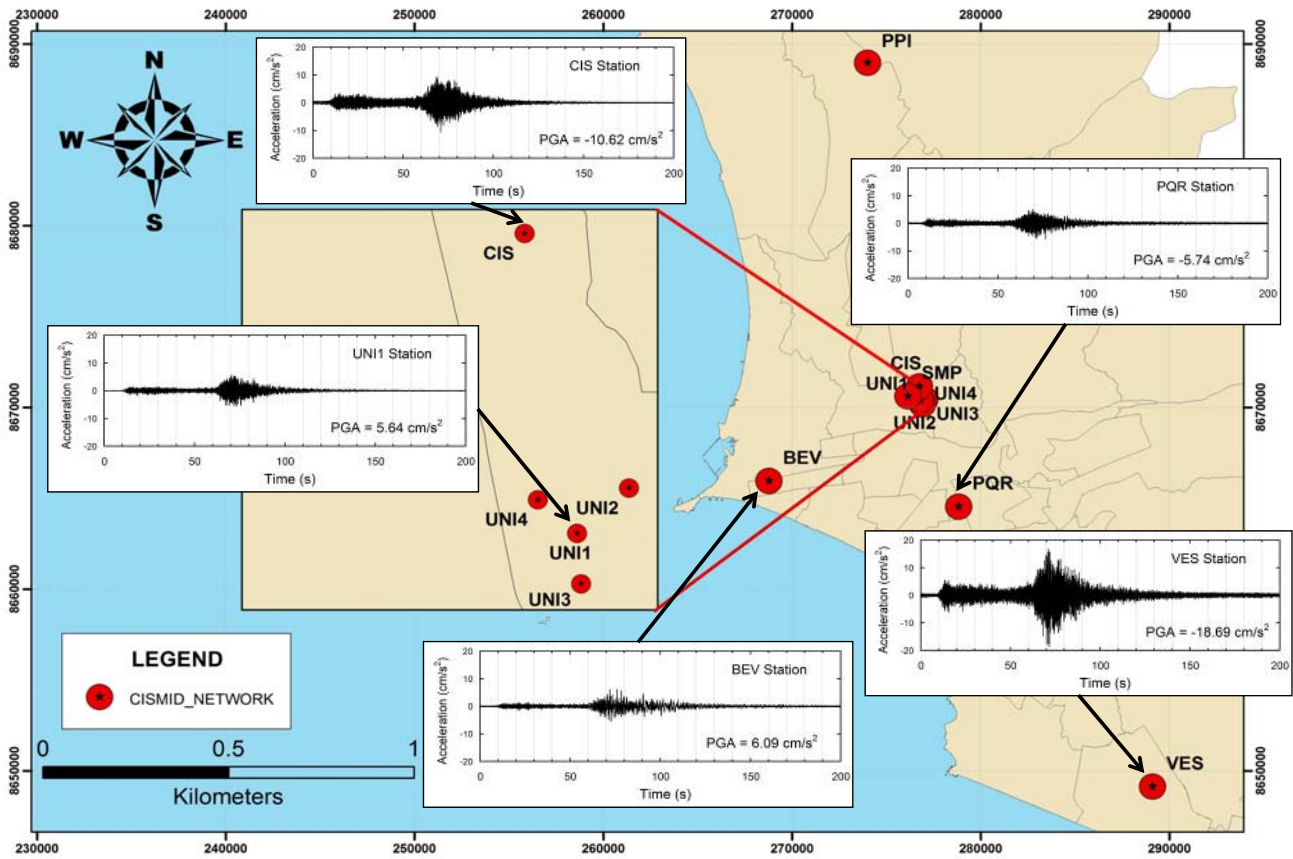




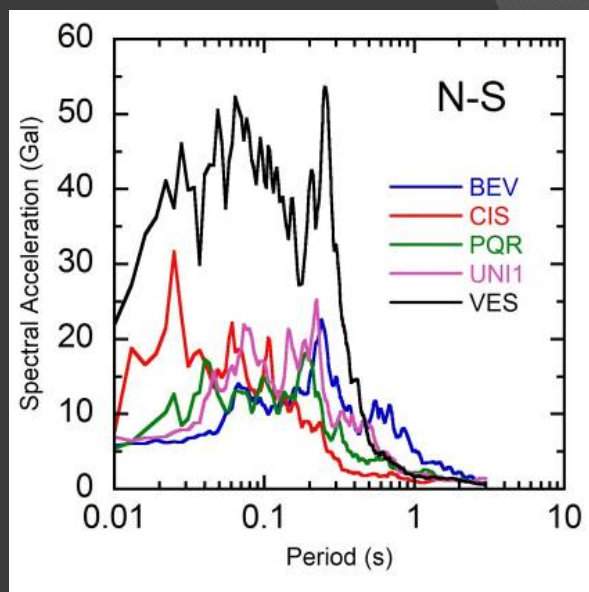
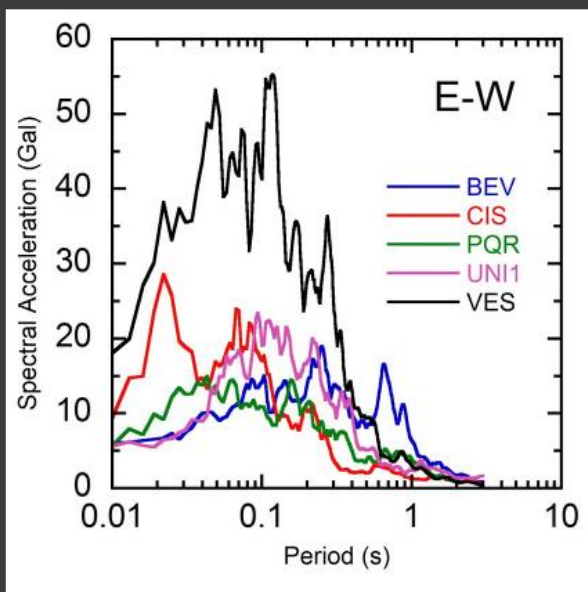
# Analysis of Recorded Data



# Contamaná Earthquake (August 24, 2011)

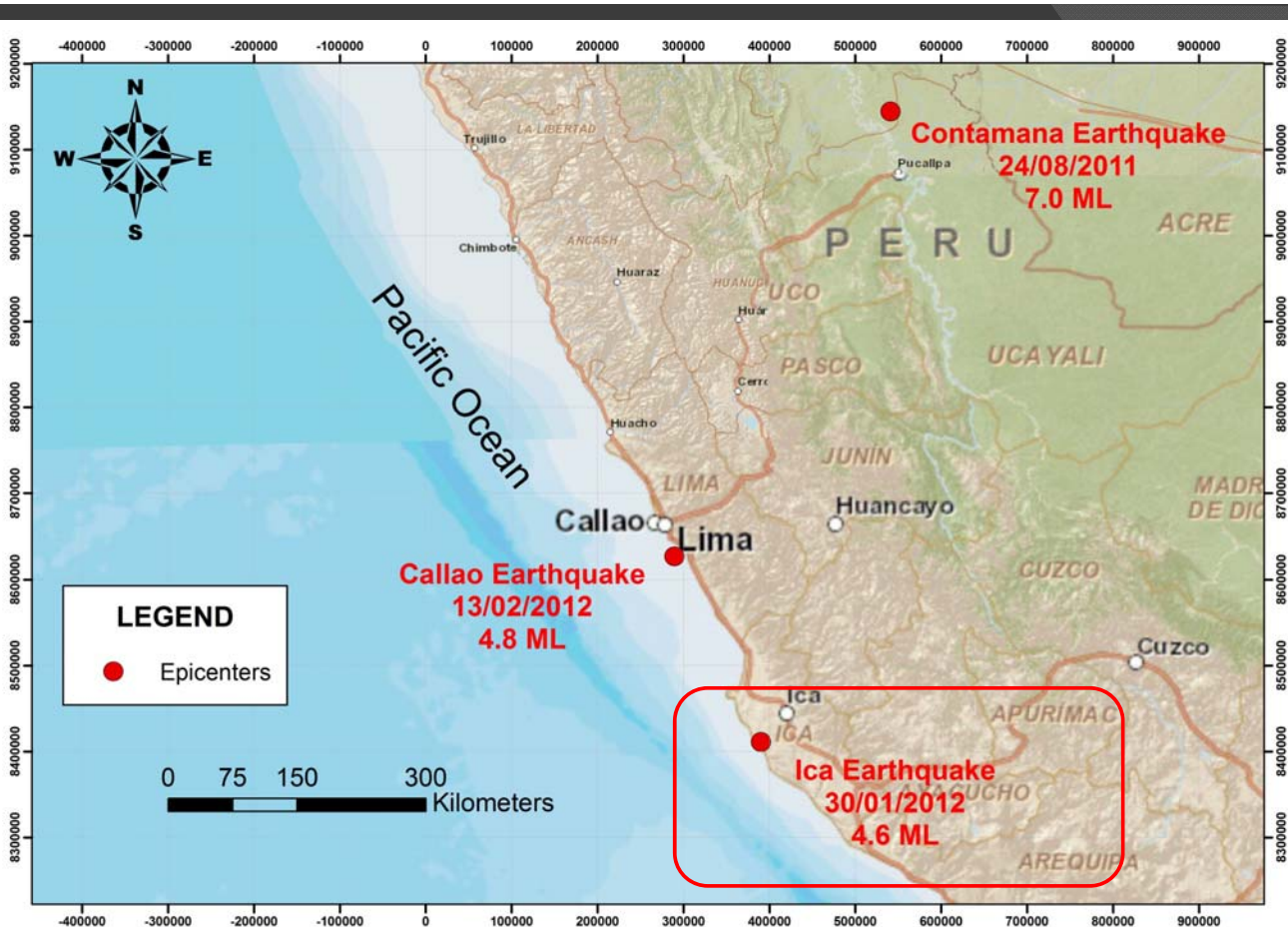
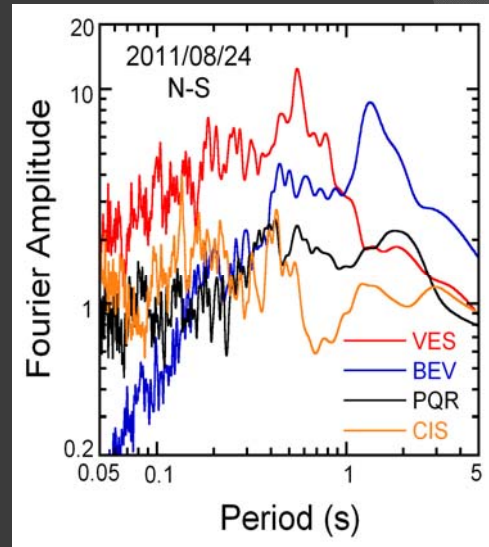
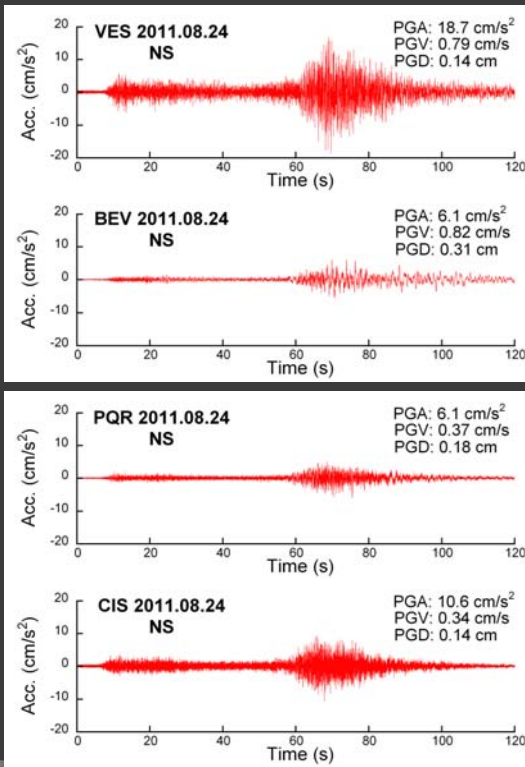


# Contamaná Earthquake (August 24, 2011) Response Spectra ( $\beta=5\%$ )

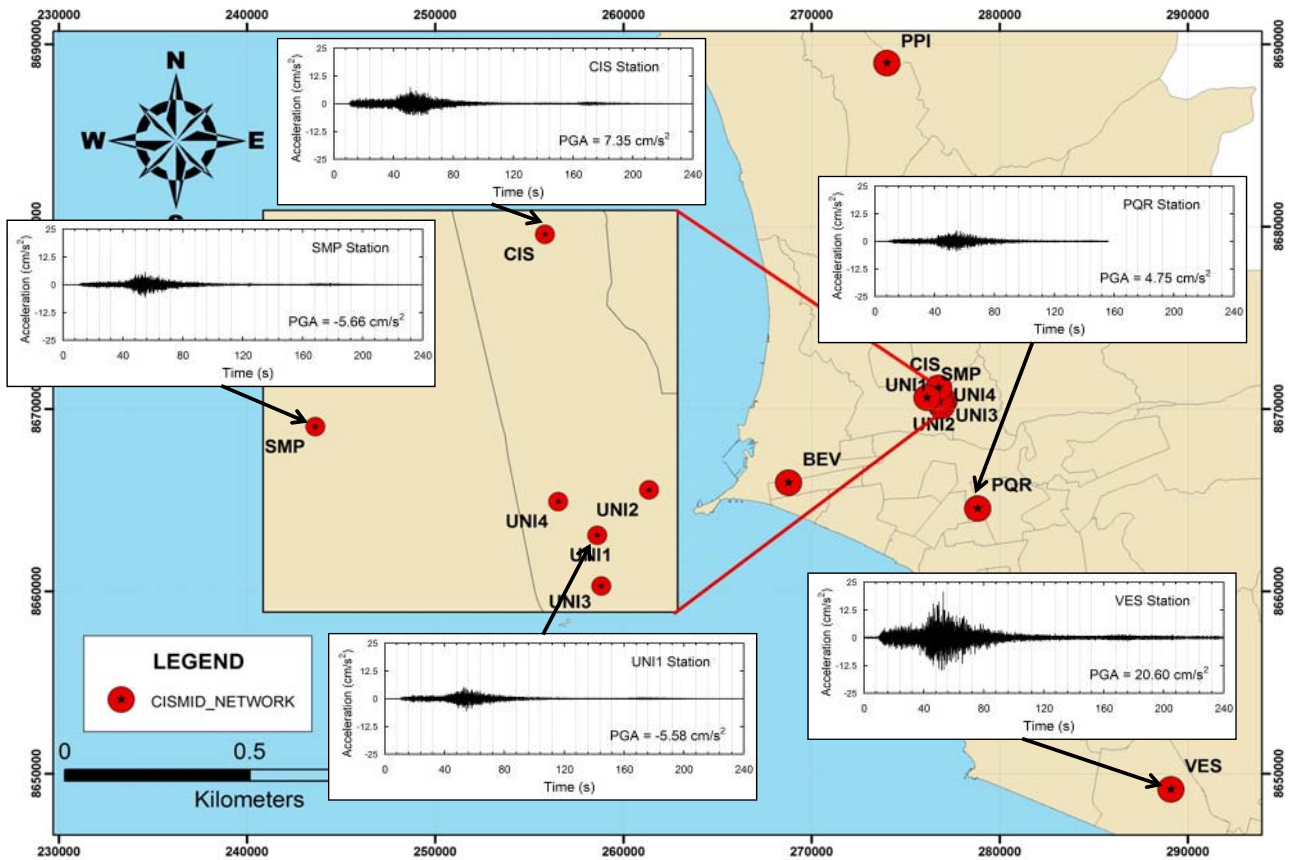




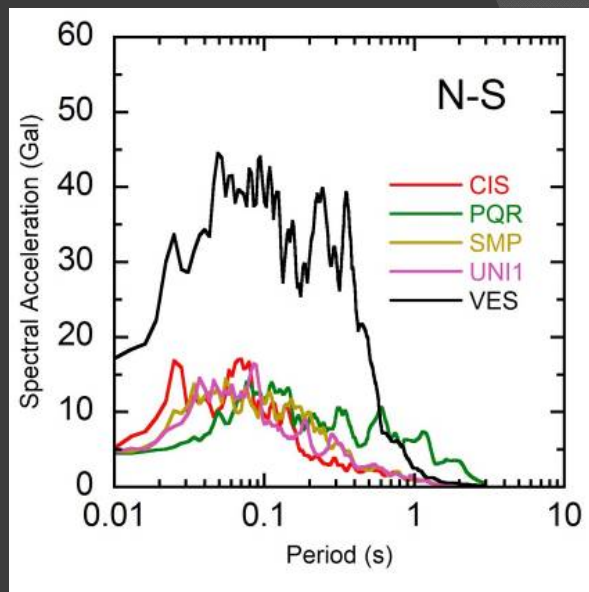
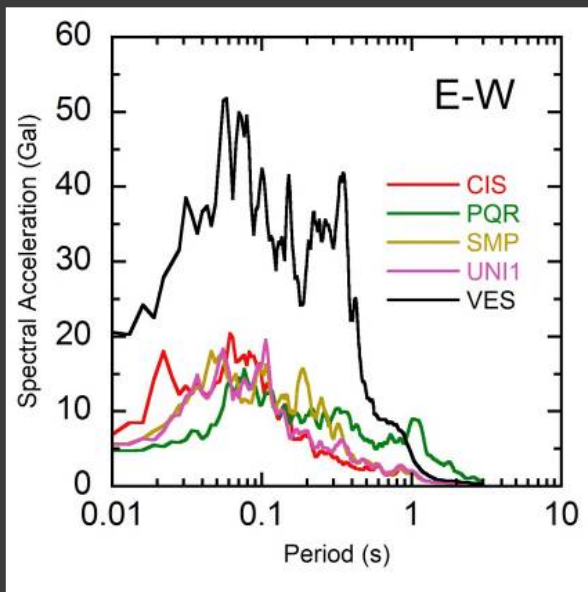
# Contamaná Earthquake (August 24, 2011) Fourier Spectra



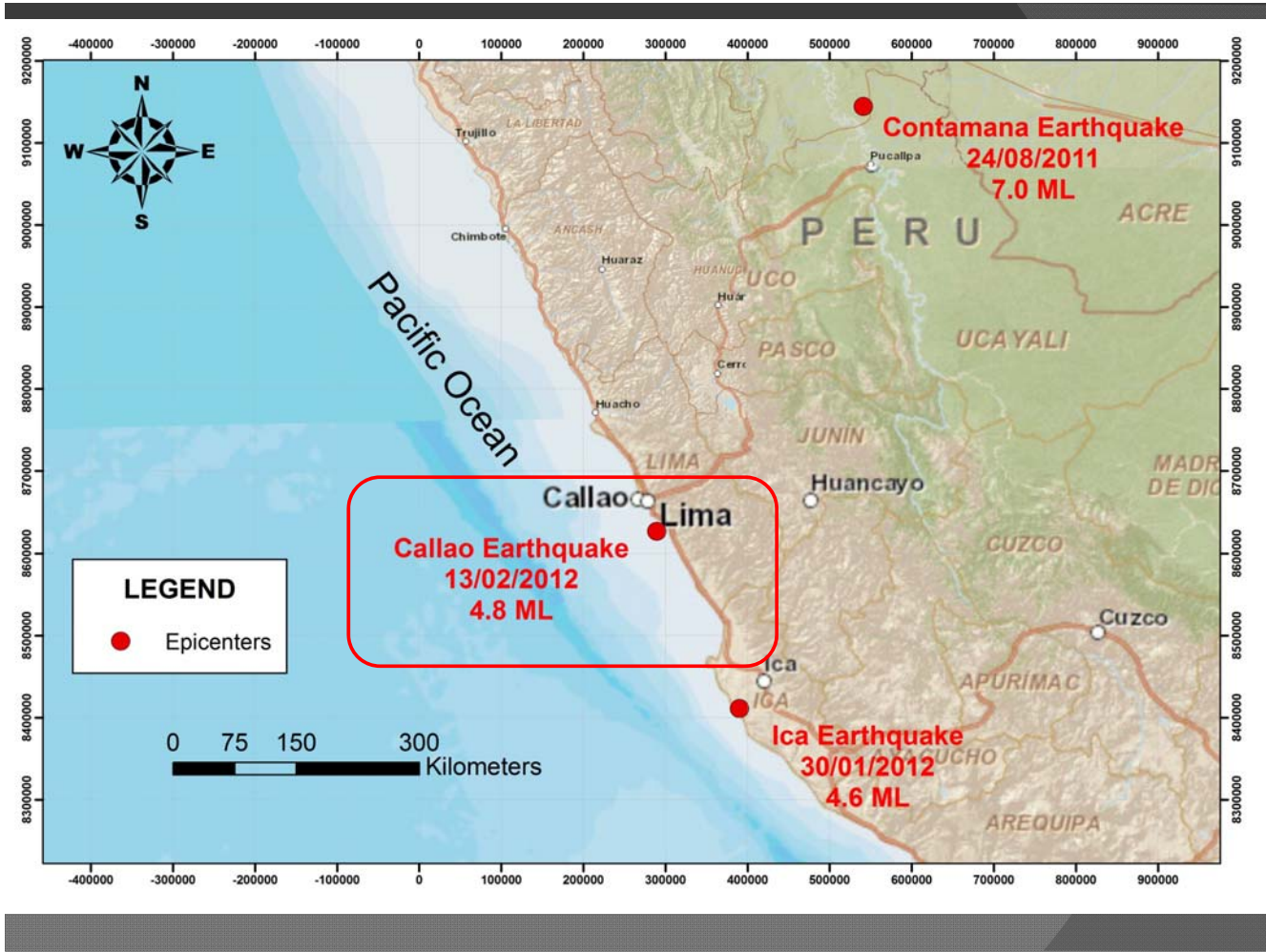
# Ica Earthquake (January 30, 2012)



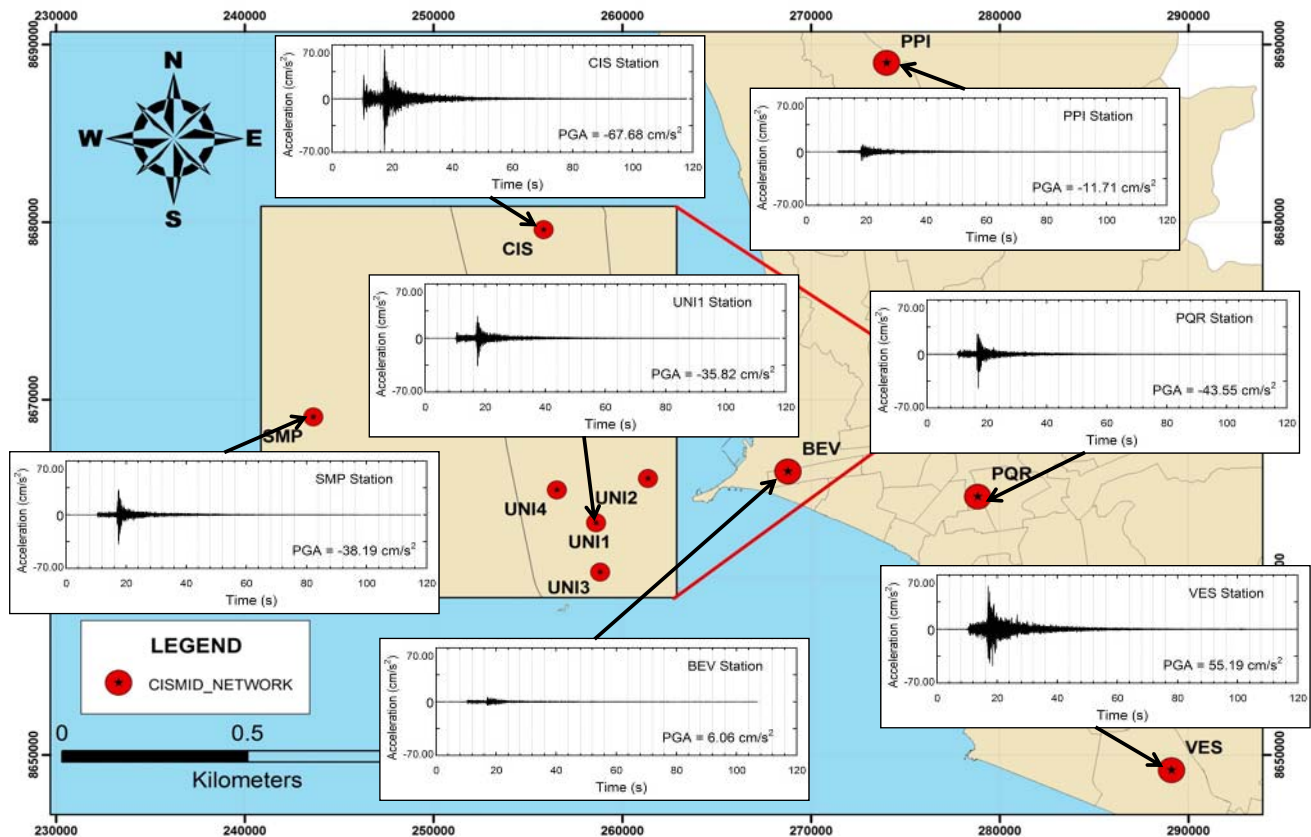
# Ica Earthquake (January 30, 2012) Response Spectra ( $\beta=5\%$ )



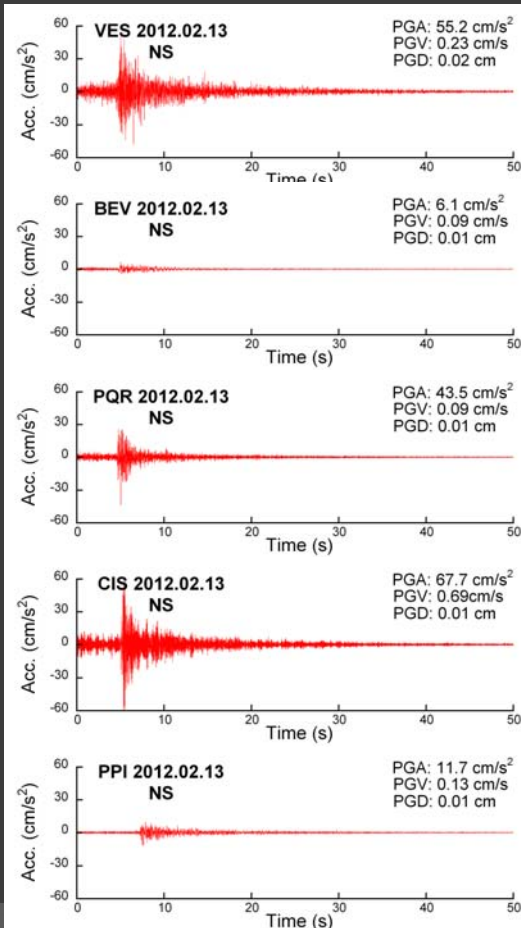
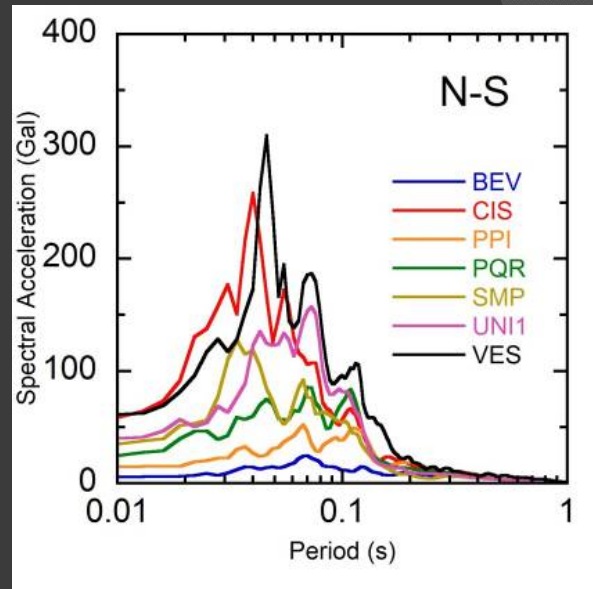
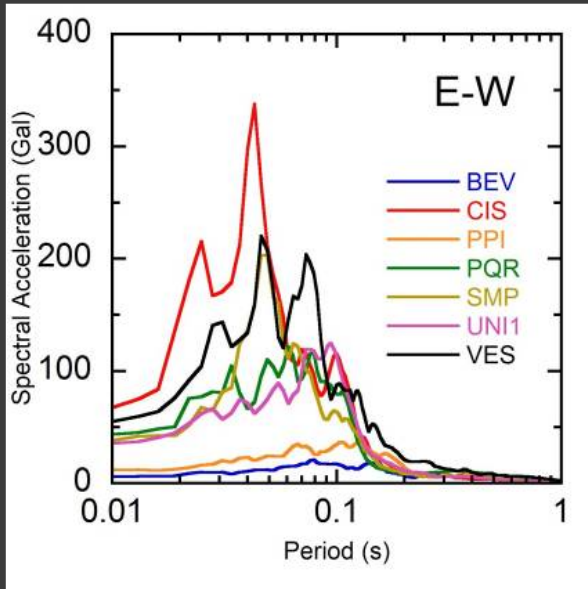




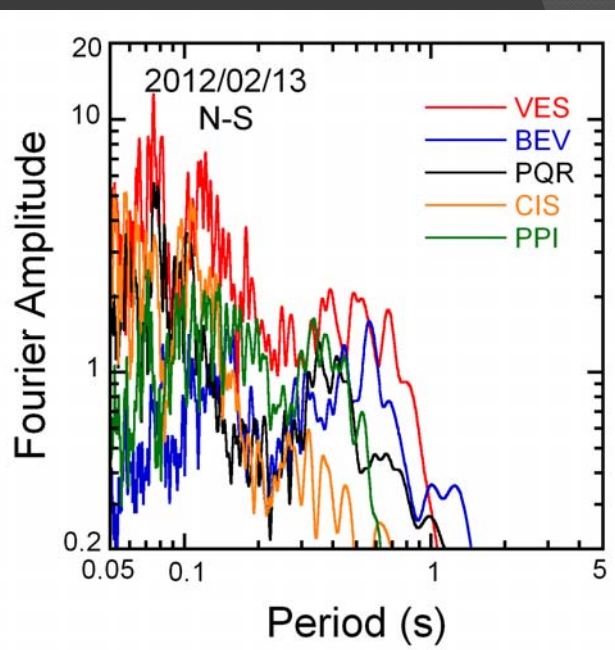
## Callao Earthquake (February 13, 2012)



# Callao Earthquake (February 13, 2012) Response Spectra ( $\beta=5\%$ )

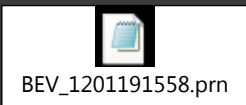


# Callao Earthquake (February 13, 2012) Fourier Spectra



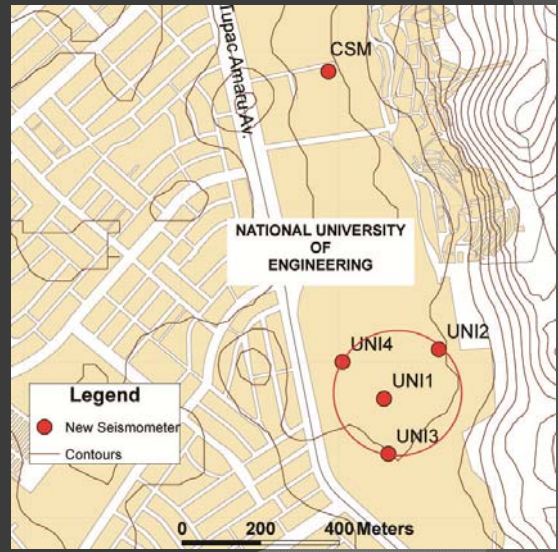
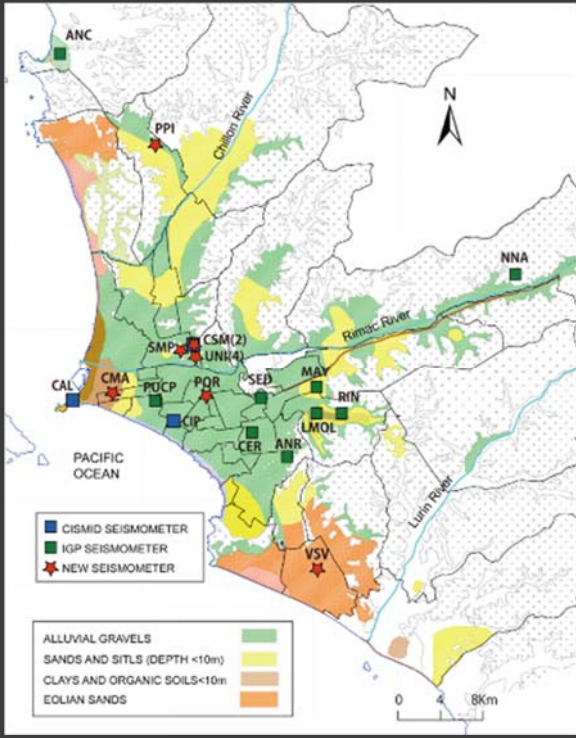


All the data from the recorded events will be available in the **Project and REDACIS** (CISMID Seismic Network) websites.



**Research Performed Using the Seismic Network Data**

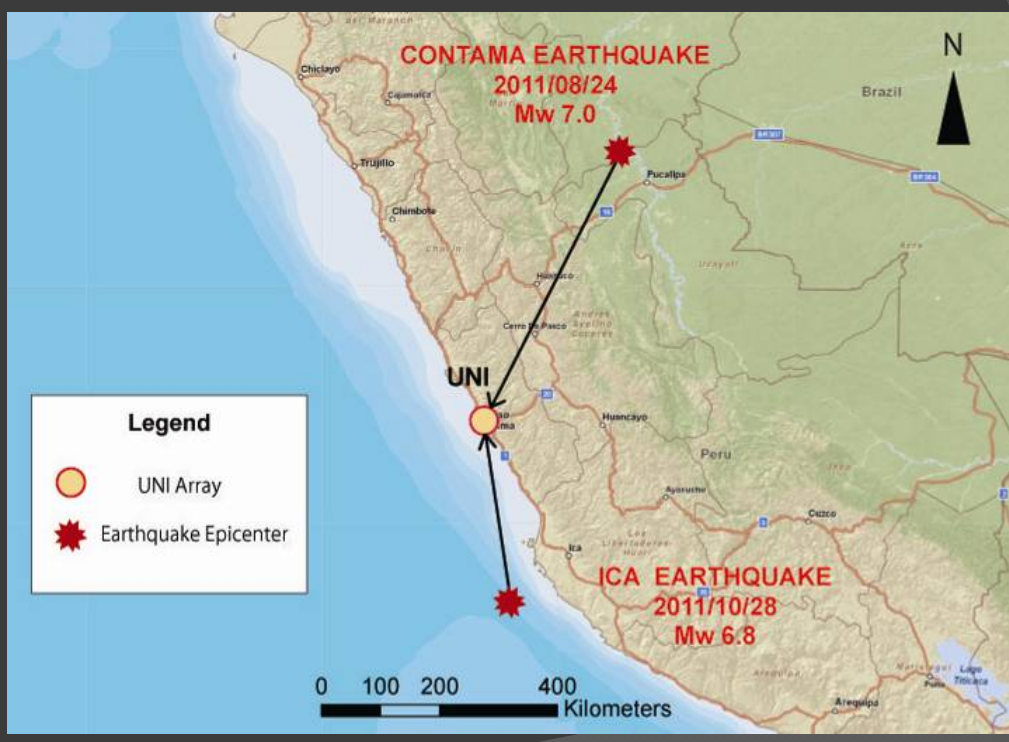
# Estimation of shear-wave velocity profiles and amplification using seismic records (Calderón D., 2012)



Array of Seismometers in UNI

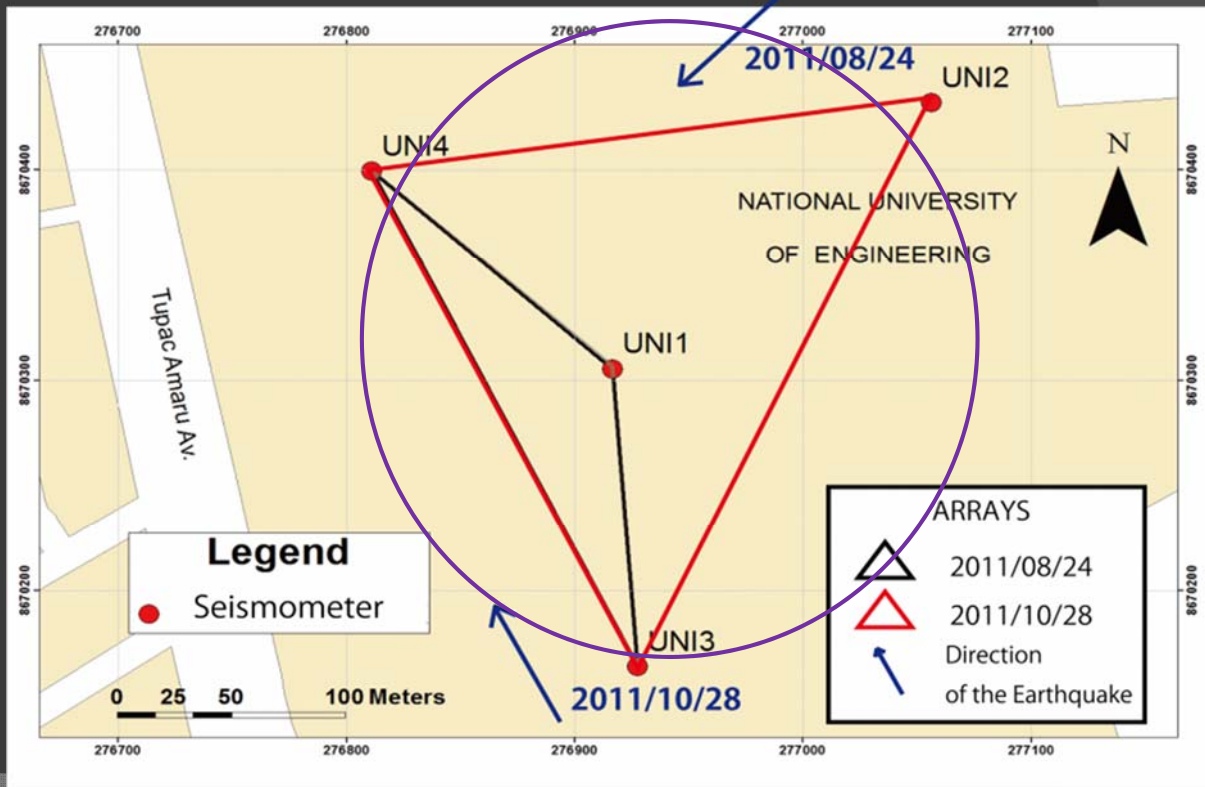
Map of Seismometers in Lima (22)

## Seismic Records used for the Analysis



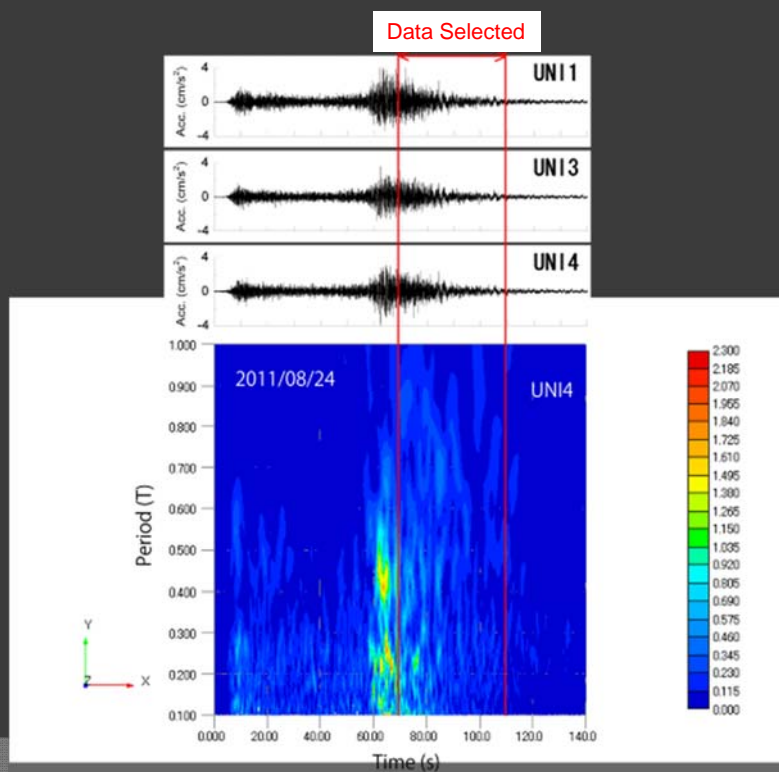


# Array of Seismometers at UNI Campus



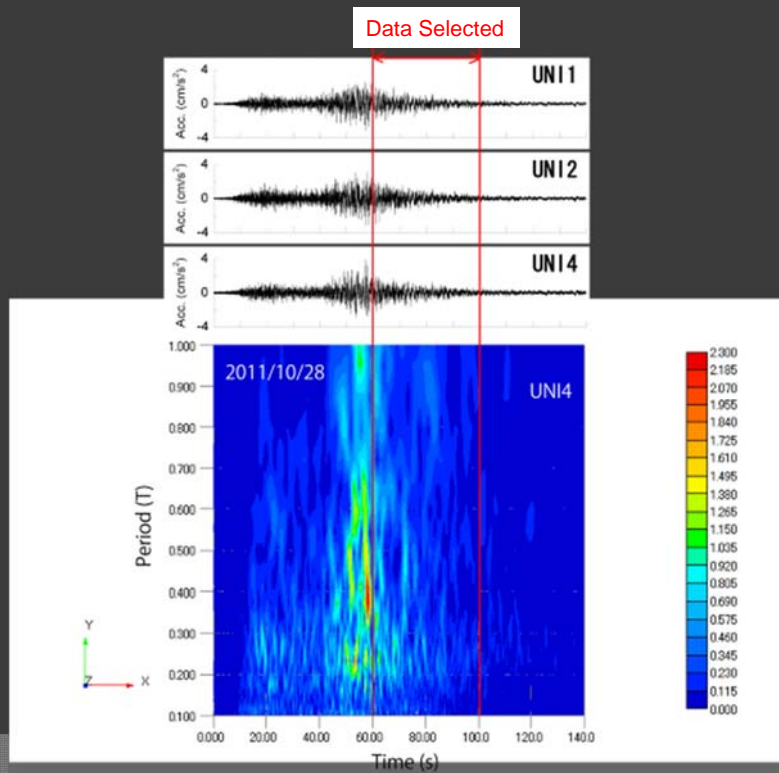
25

# Selection of Earthquake data (2011/08/24)

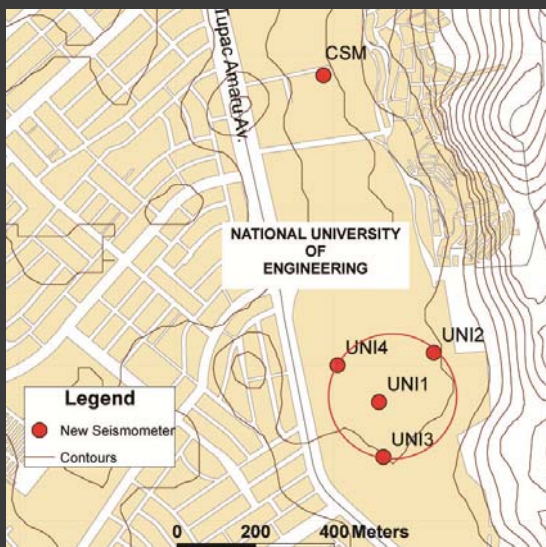


26

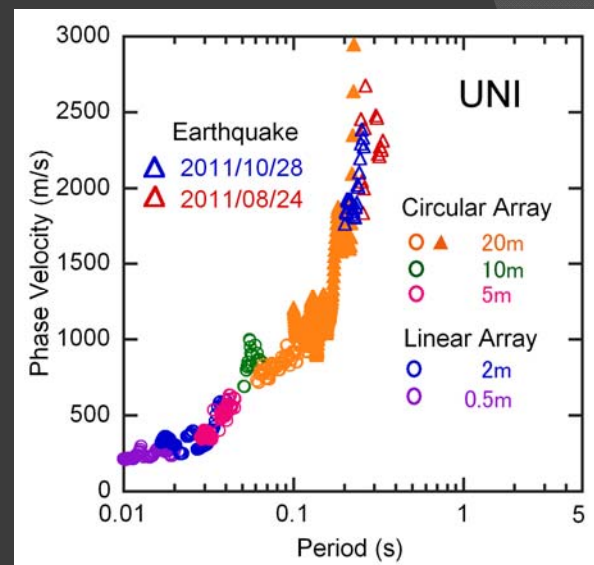
# Selection of data Earthquake (2011/10/28)



# Estimation of shear-wave velocity profiles and amplification using seismic records (Calderón D. 2012)

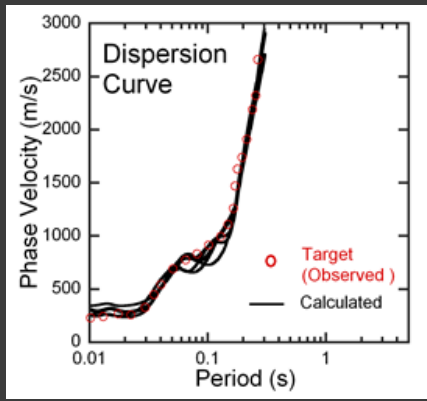


Array of Seismometers in UNI

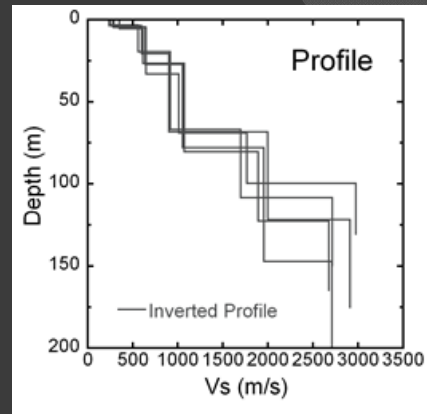


Dispersion Curve

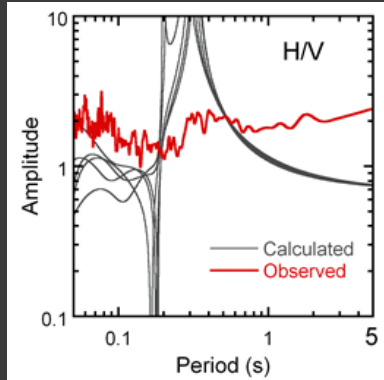




Comparison between observed and calculated dispersion curves

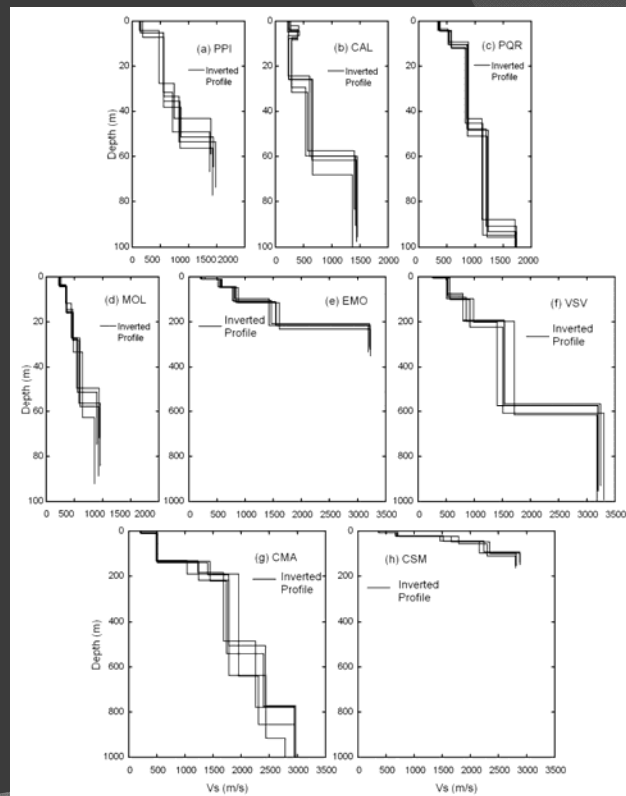
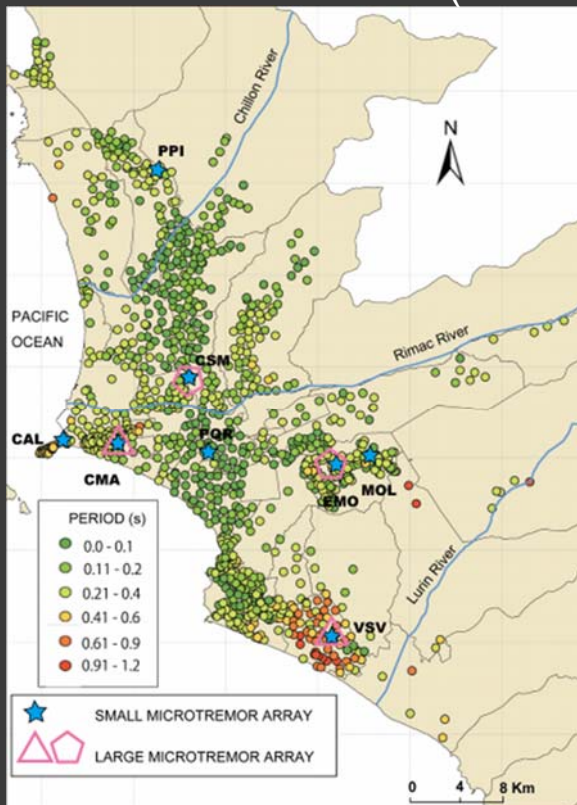


S-wave profiles obtained by the inversion of the observed dispersion curve

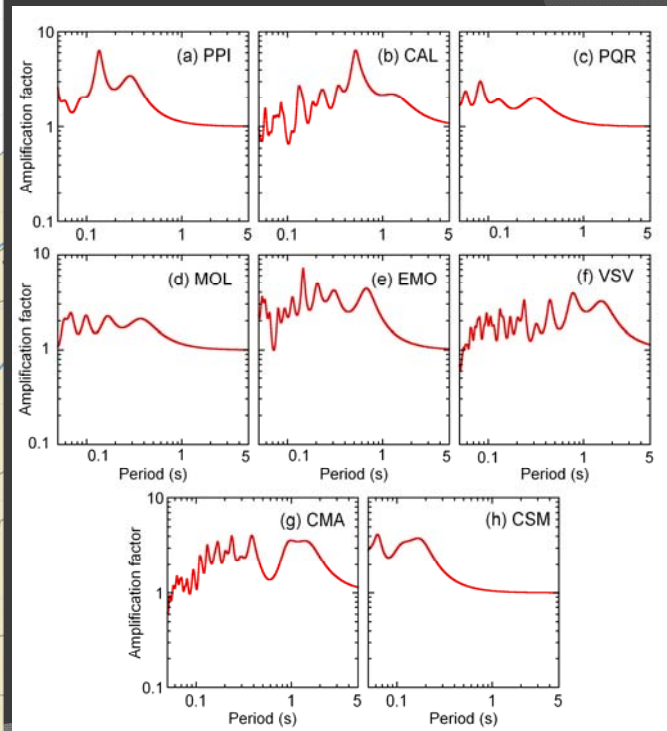
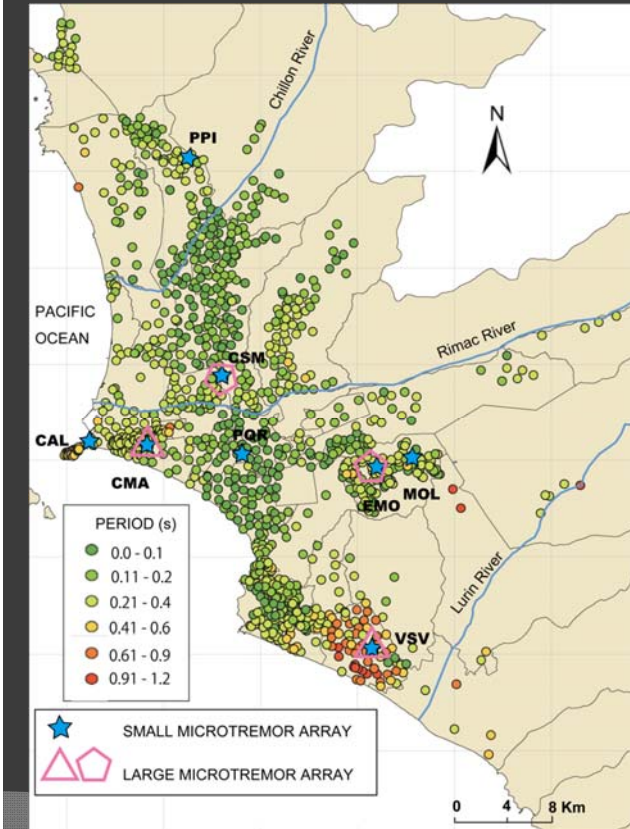


Comparison between observed and calculated H/V Spectrum

## Estimated shear-wave velocity profiles in Lima City (Calderón D., 2012)

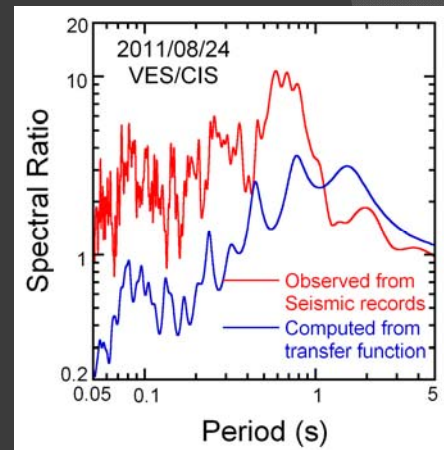
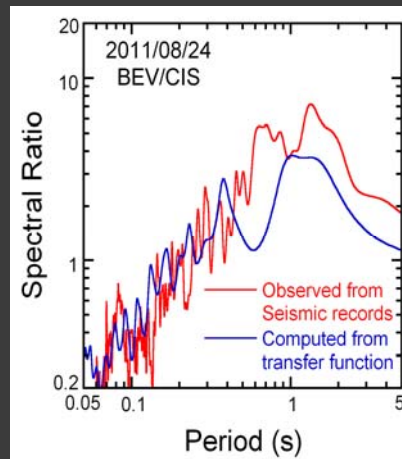
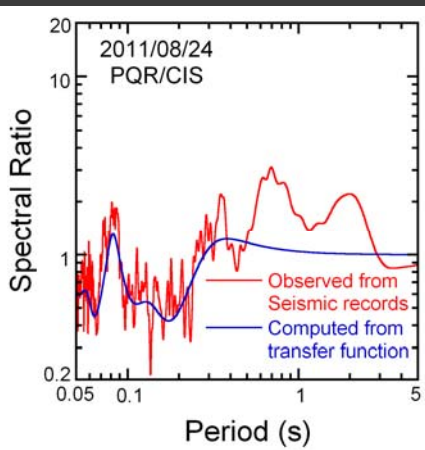


# Estimated Transfer Function in Lima City (Calderón D., 2012)



31

# Spectral Ratios from Seismic Records and Transfer Functions (Calderón D., 2012)

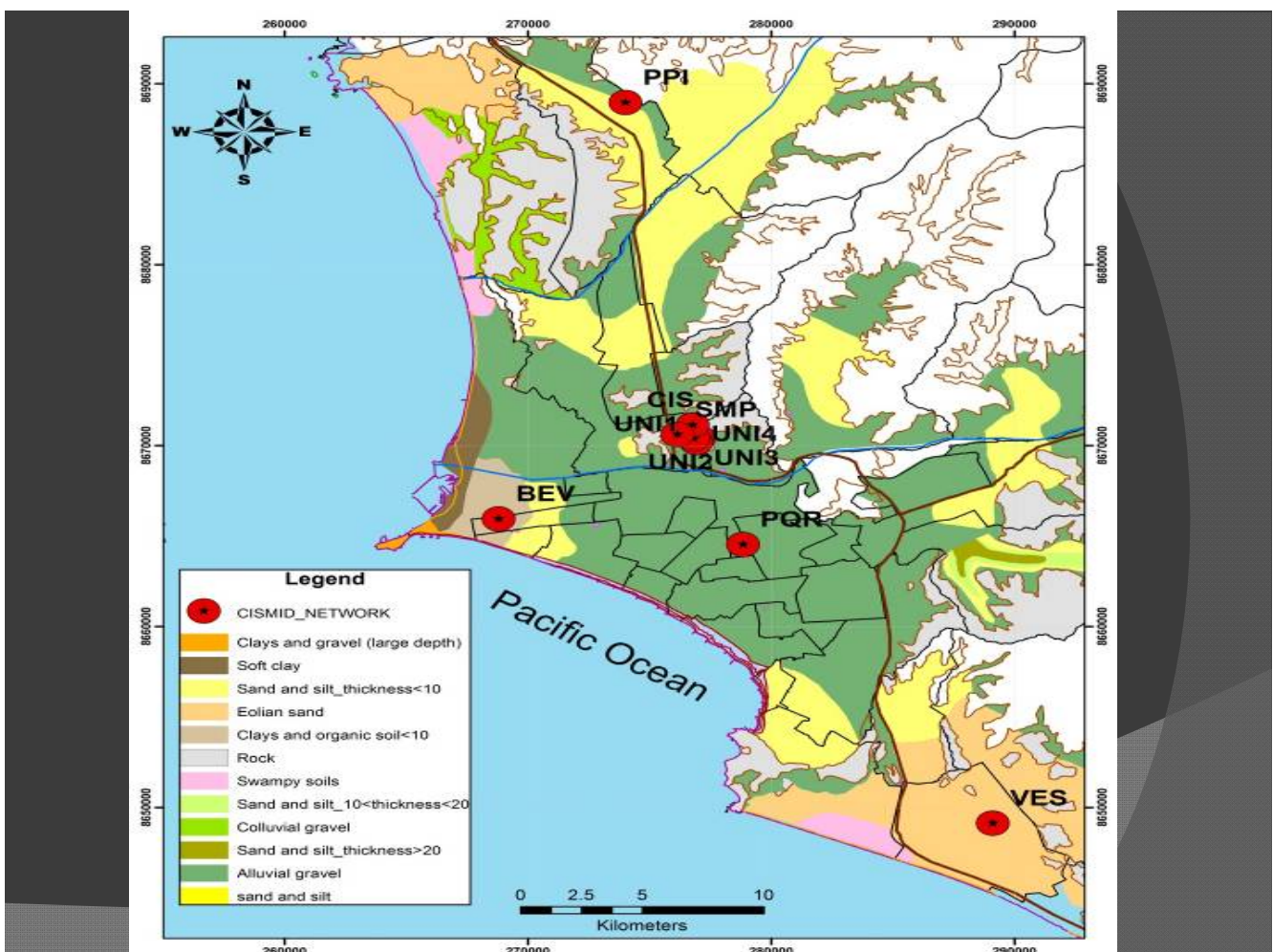




## CONCLUDING REMARKS

### Second Stage:

- Borehole and PS Well Logging at three Seismic station will be performed.
- Array observation in Callao and Villa el Salvador will be performed.
- Site amplification based on topography in Lima City.
- Installation of Accelerometers in Tacna City





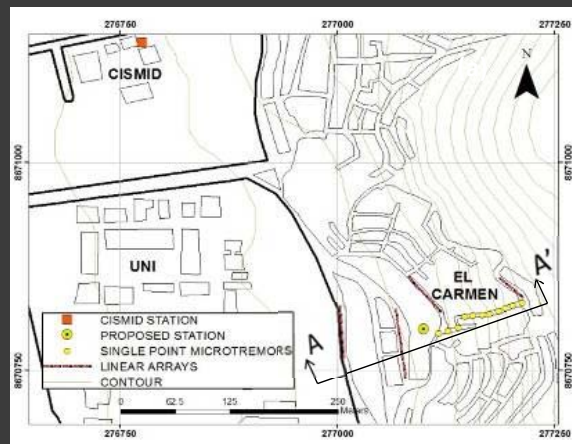
# A study of the effects of the irregular topography in the seismic response of populated steep slopes in Lima city (González C. 2012-2014)



Heavily populated slope in Independencia (in the east side of CISMID)

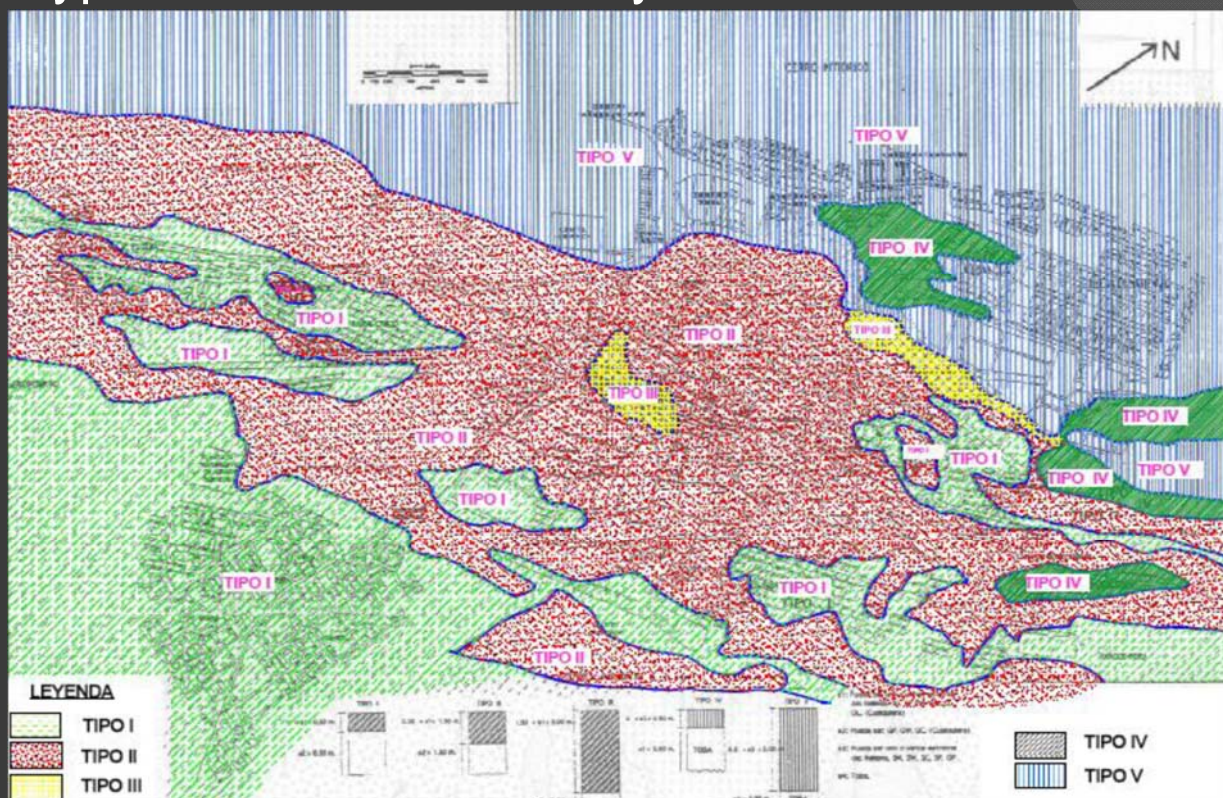
There are sufficient evidences indicating that under certain conditions, seismic energy can be amplified due to the effect of topography (Celebi 1991, Kurita et. al. 2003).

The objective of the research is to estimate the dynamic behavior of the ground in populated steep slopes in Lima city. In order to accomplish this objective, microtremor and seismic motion observations will be carried out from which 2-D finite element models will be generated.



Proposal of single microtremor measurements, linear arrays and location of a new accelerometer

# Type of soils in Tacna City







**THANK YOU.**