Strong Motion Estimation and Seismic Microzoning in Major Cities in Peru

Research Plan of **G1 Group**
(Seismic Motion and Geotechnical / SMGT Group)

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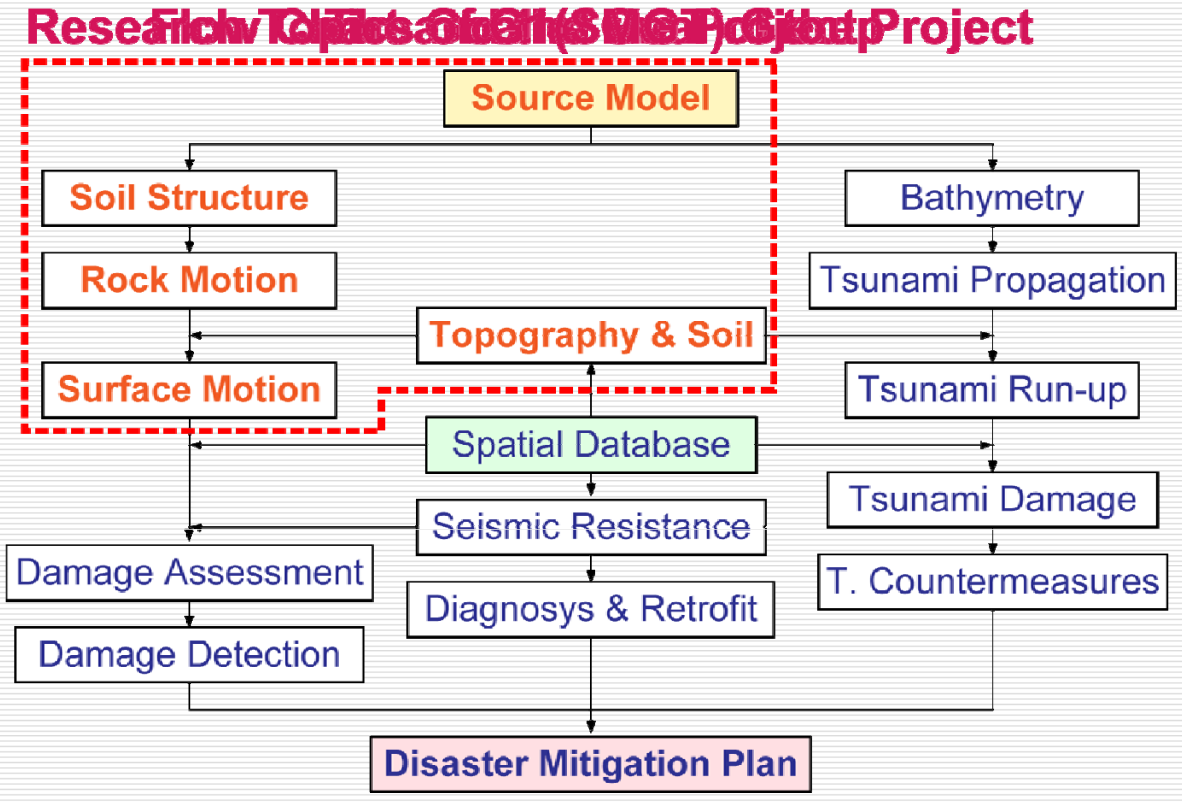
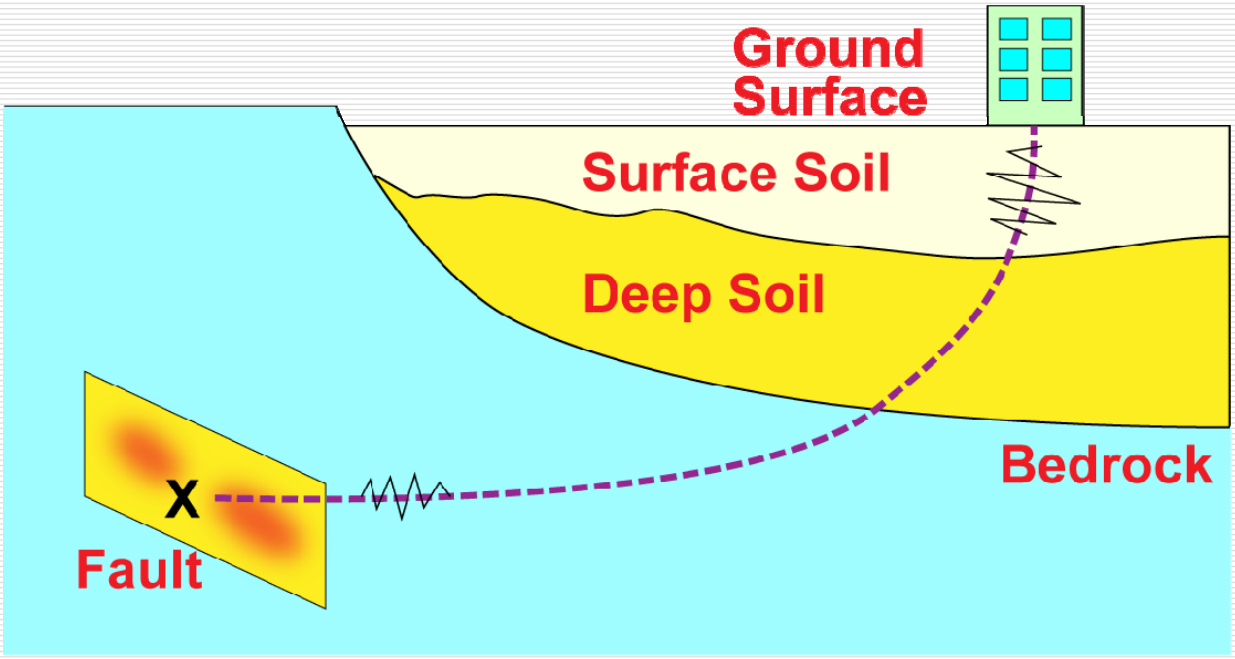
March 15, 2010

Overall Flow Chart of the Project

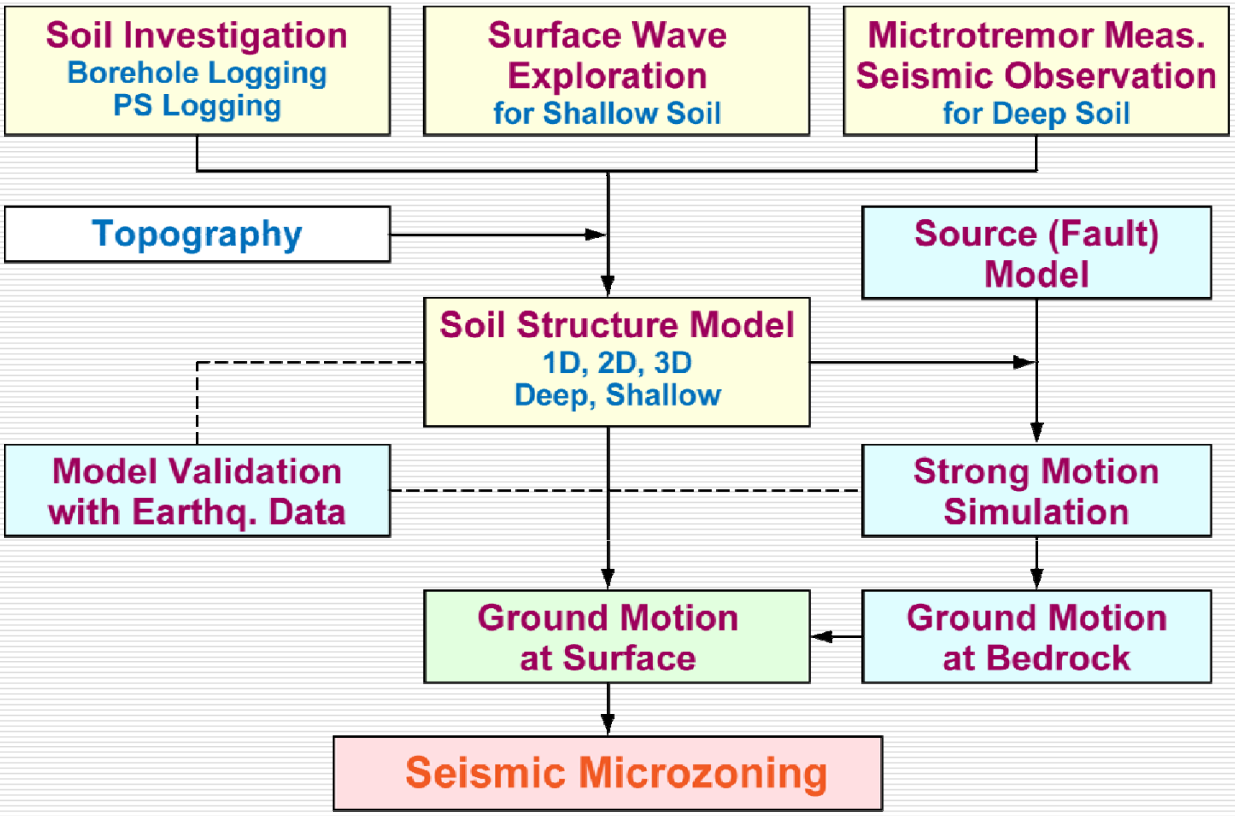


Strong Motion Prediction



Fault Model → Deep Soil Structure → Surface Soil Structure

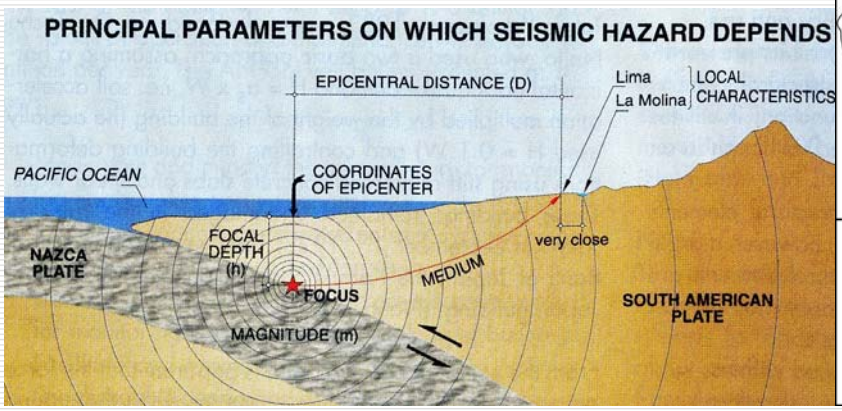
Research Topics of G1 (SMGT) Group

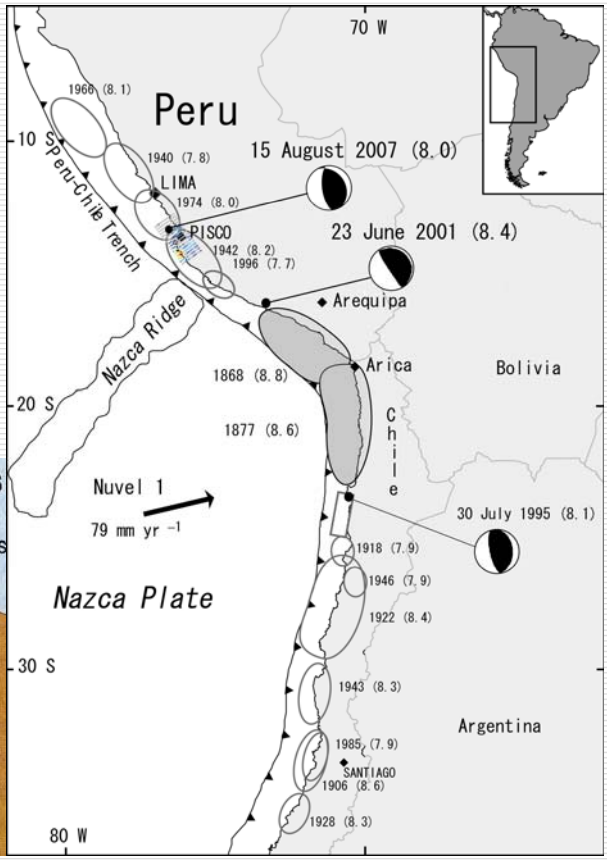


Strong Motion Records and Historical Seismicity

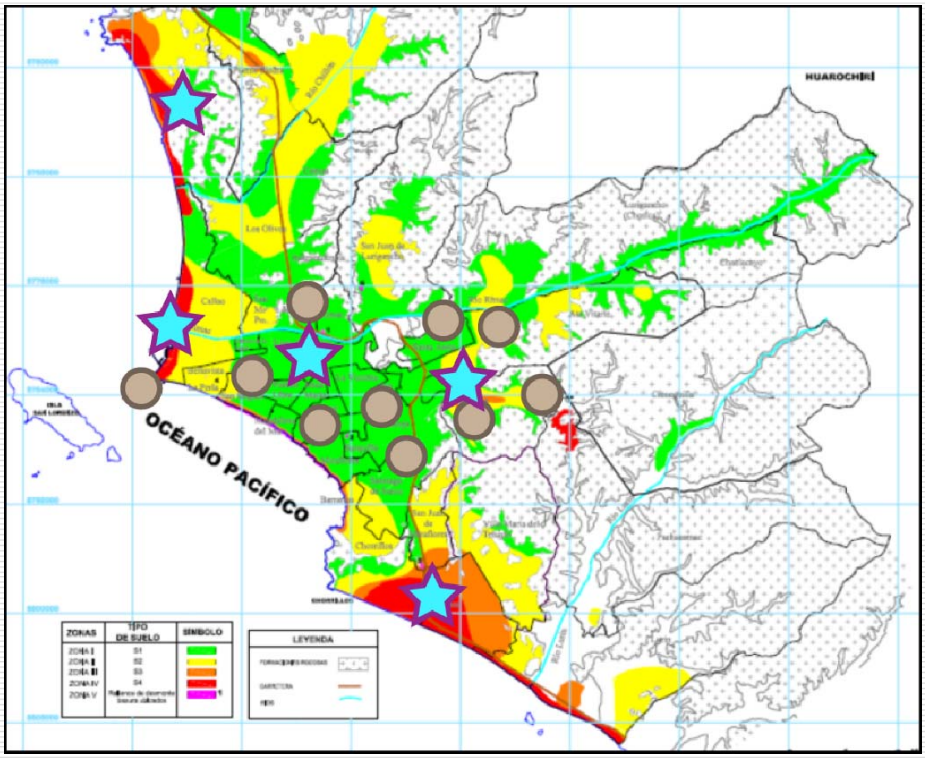
1960 01 13 Arequipa, Peru M7.5
1966 10 17 Barranca M8.1
1970 05 31 Chimbote, Peru M7.9
1974 10 03 Lima M8.1
2001 06 23 Atico M8.4
2007 08 15 Pisco M8.0

2010 02 27 Offshore Maule, Chile M8.8



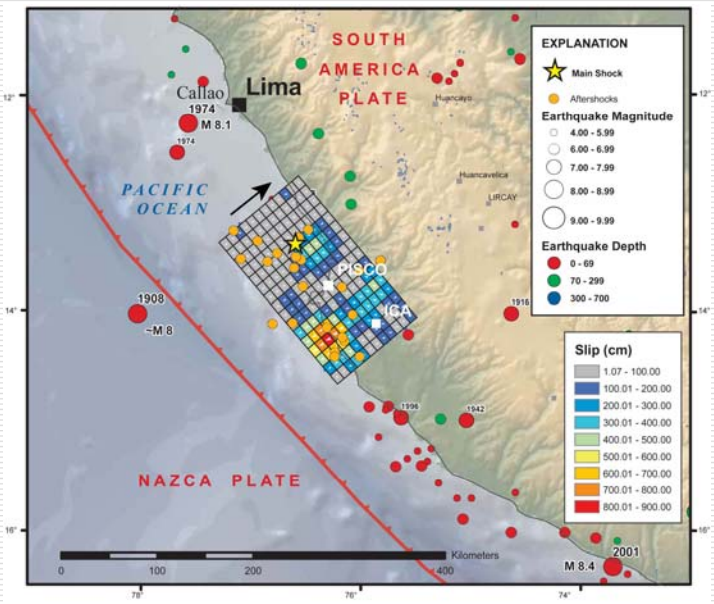


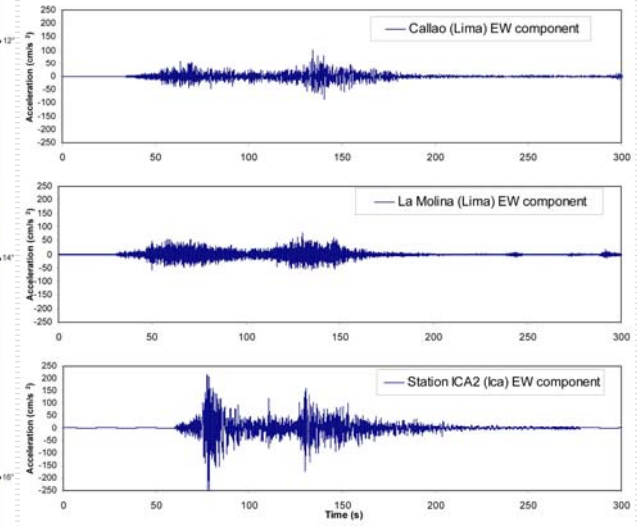
Strong Motion Observation



Existing New

Source Model and Strong Motion Simulation

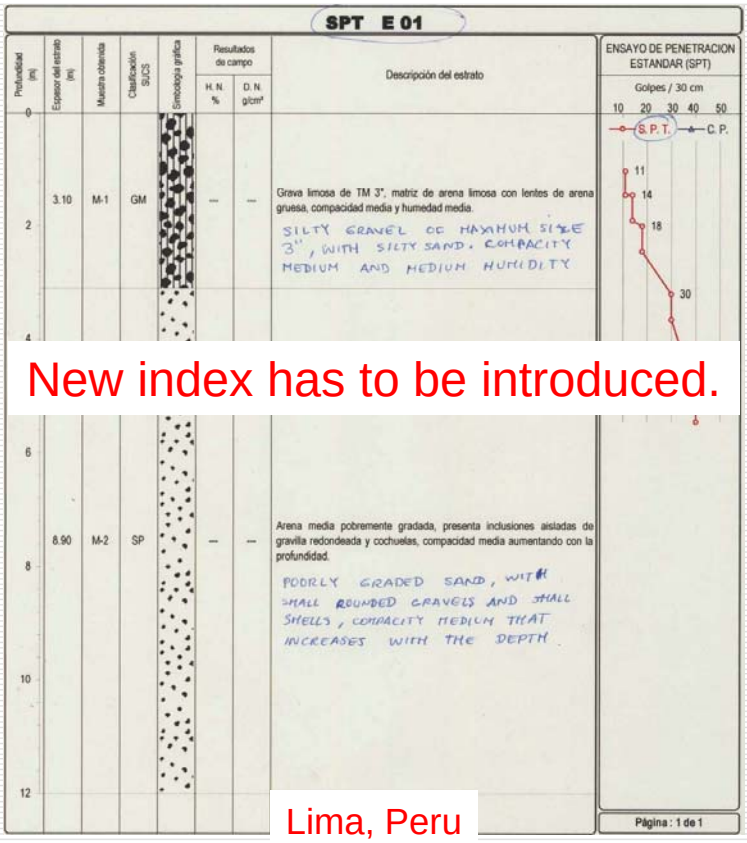




Construction of Source Model

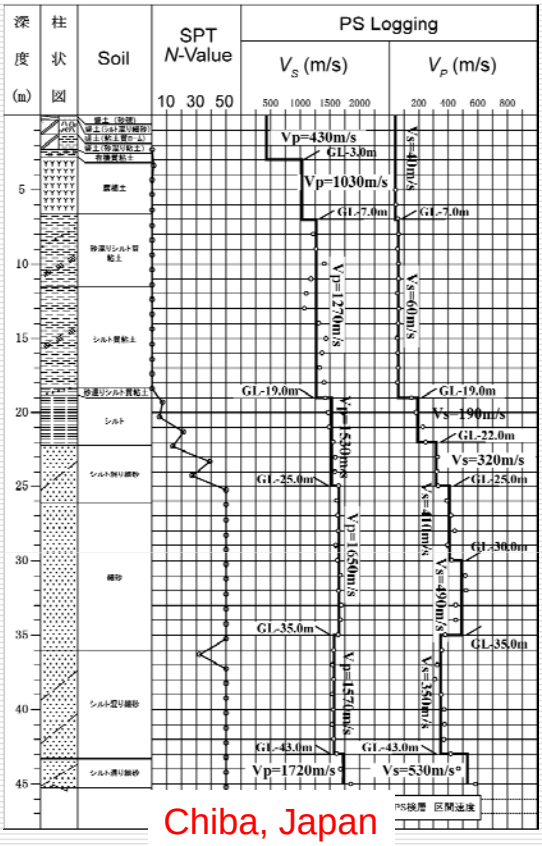
Strong Motion Simulation by 3D Finite Difference Method

Surface Soil Investigation (1)



New index has to be introduced.

Lima, Peru



Chiba, Japan

Surface Soil Investigation (2)

- Borehole and PS logging will be conducted at several sites to examine the soil profiles and the soil properties of the surface soil.

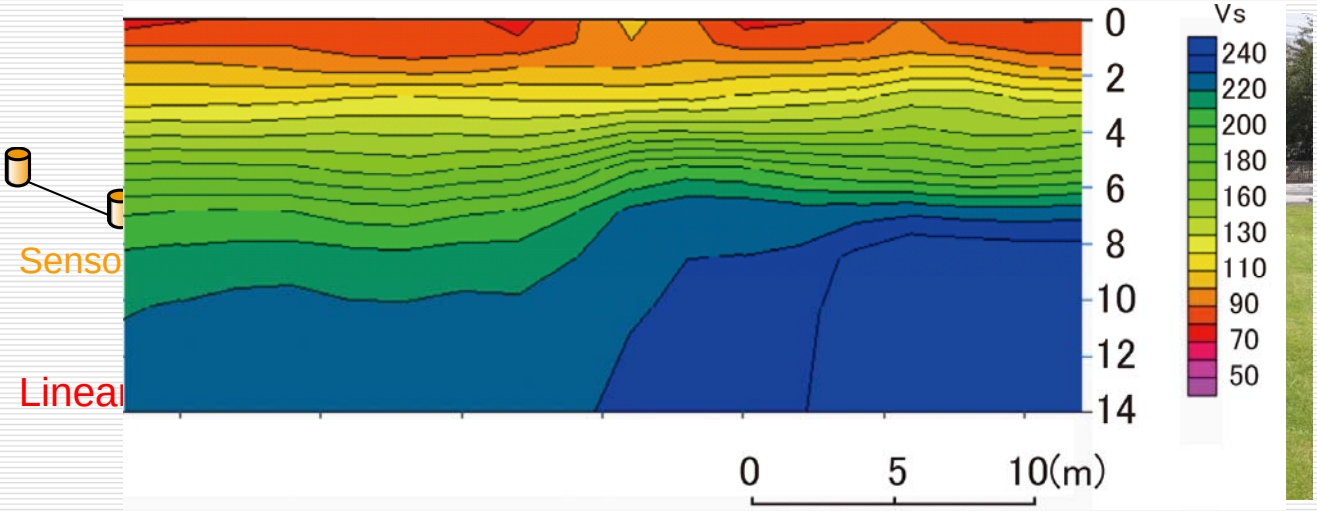
Borehole

PS Logging

Surface Wave Method

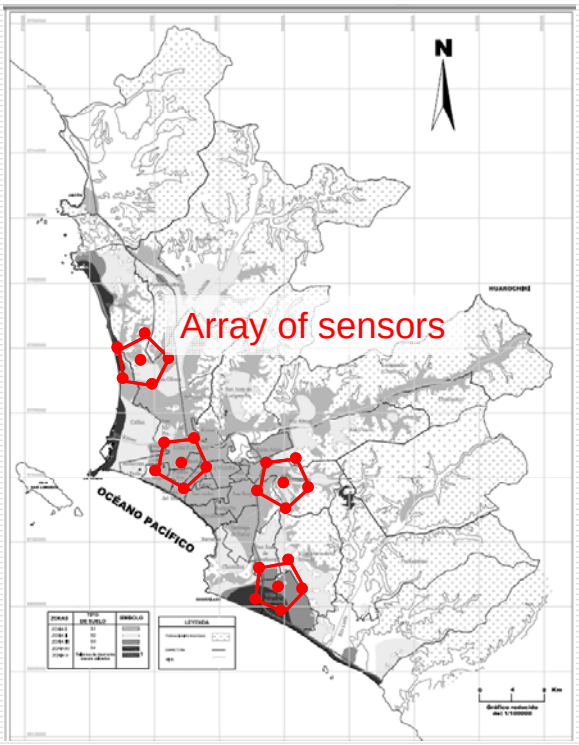
- In order to estimate the shallow soil profiles, the surface wave method will be conducted, in addition to single point / array microtremor measurements.

S-Wave Velocity Profile

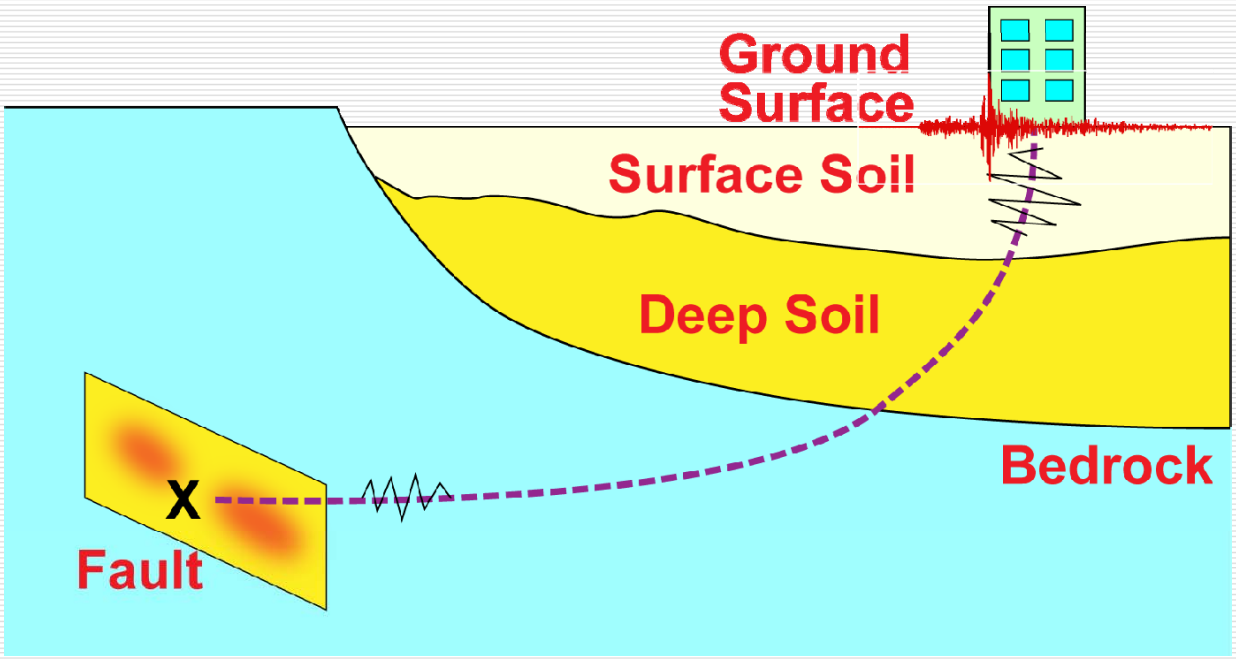


Array Measurement of Microtremors

- Array measurements of microtremors are conducted in several locations in order to estimate the deep soil profile of the target site in 1D, 2D or 3D.



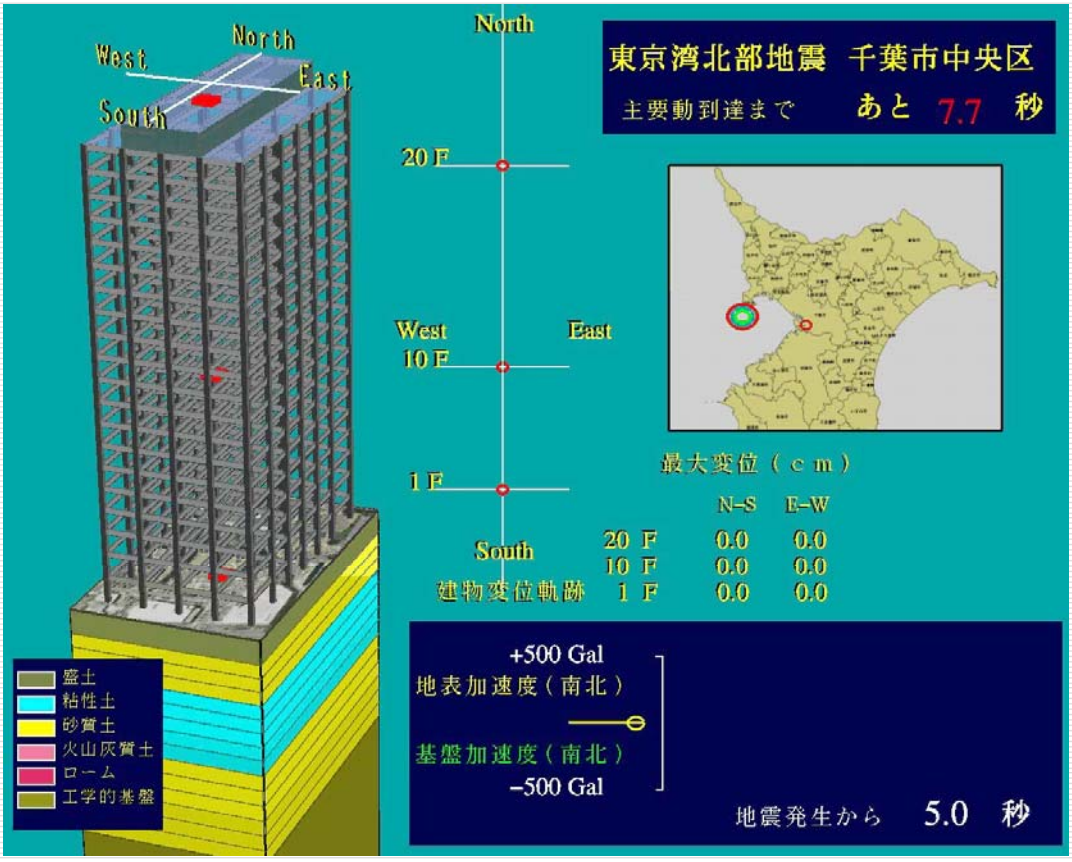
Strong Motion Prediction



Fault Model → Deep Soil Structure → Surface Soil Structure → Strong Motion Prediction Analysis based on Wave Prop. Theory

Prediction of Ground Motions

Prediction of Response of Buildings

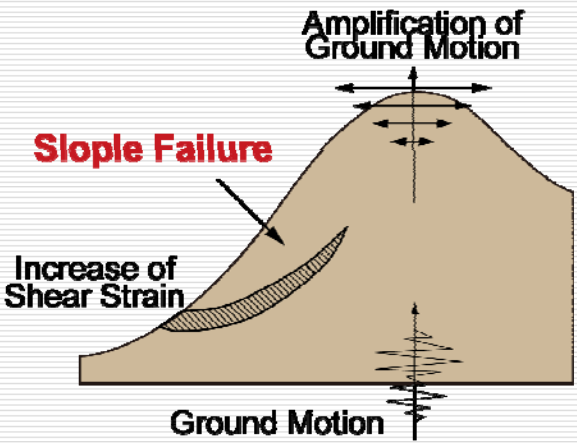


Prediction of Tsunami Run-up

Seismic Risk of Slopes

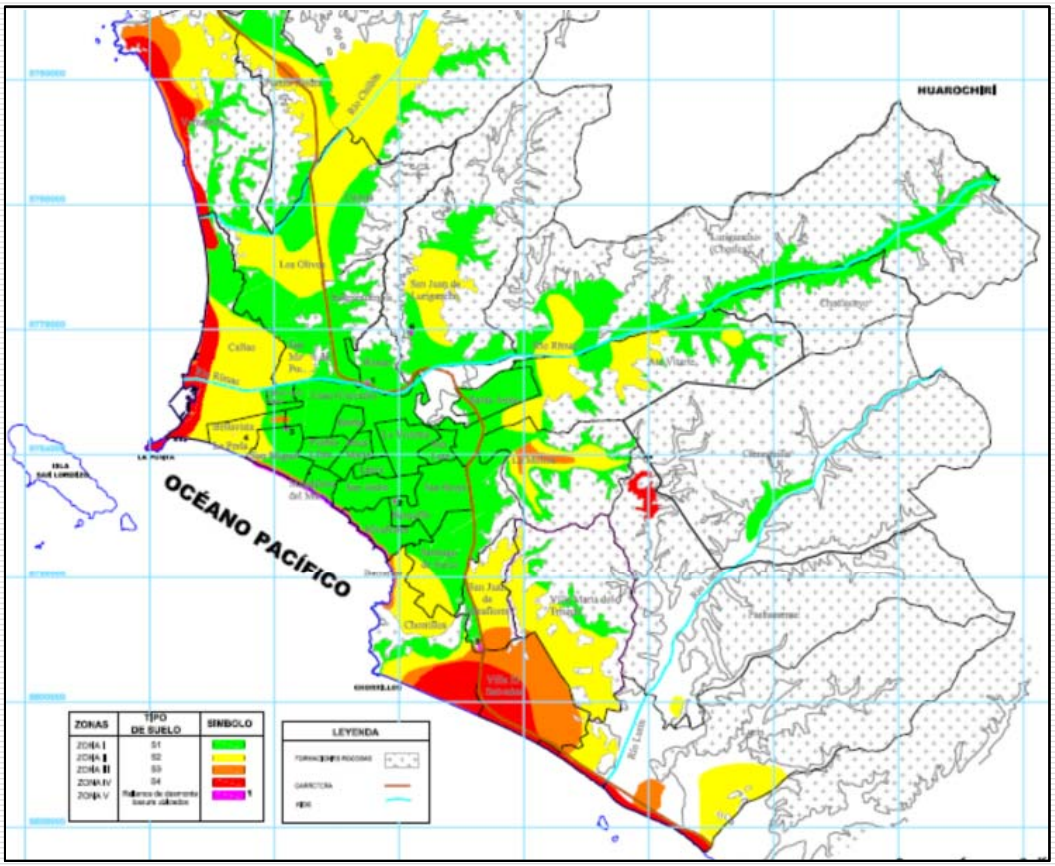
- In Lima, there are many steep slopes where houses are densely built.
- Ground motion tends to become large due to ground irregularity (slopes), which may cause failure or landslide during an earthquake.

Densely built houses in Lima



Slope failure during EQ

Seismic Microzoning

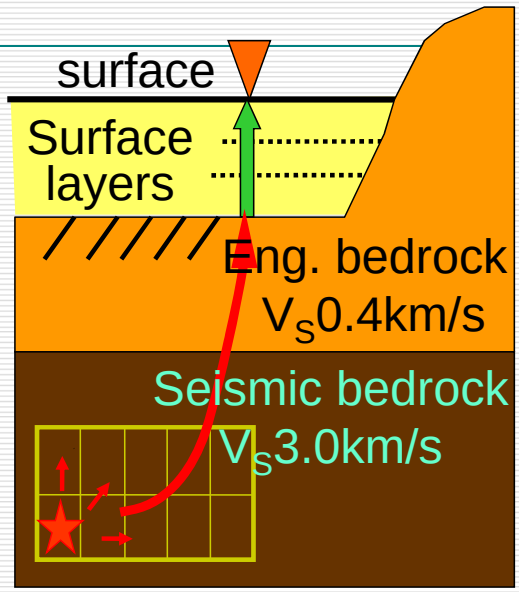


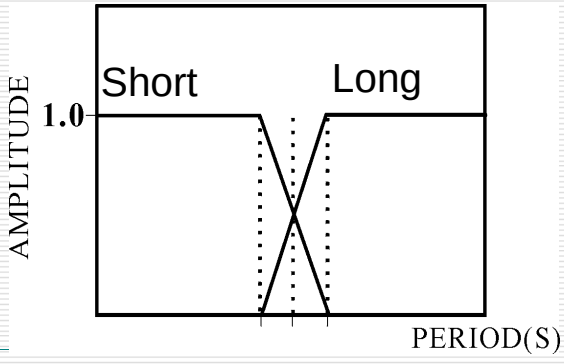
Summary: Research Plans of G1 Group

- Construction of fault models for large scenario earthquakes along the subducting plate.
  - Survey of historical seismic activities.
  - Strong motion observations by installing seismometers.
- Construction of deep and shallow soil models.
  - Geophysical and geotechnical surveys including borehole and PS loggings.
  - Surface wave and microtremor measurements.
  - Analysis of earthquake data from small events.
- Construction of microzonation maps.
  - Strong motion simulation based on fault models and deep/shallow soil models.
  - Estimation of amplification due to surface soils.
  - Estimation of slope failure.

Strong Motion Simulation

- Simulation of broadband strong motion on engineering bedrock from different scenario earthquakes in Lima, Pisco and Arequipa areas using a hybrid approach.
- 3D FDM in long-period range, and stochastic method using 1D model in short-period range).
- Calculation of surface motion considering 1D amplification in surface layers due to input motion on engineering bedrock.

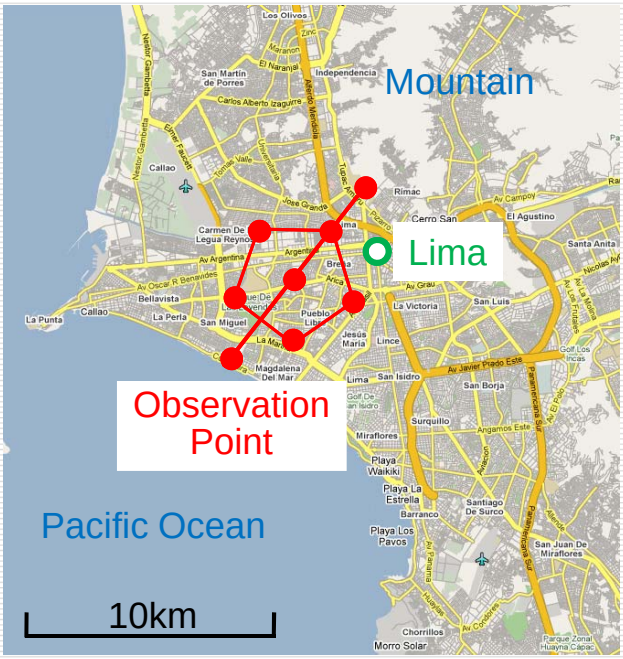




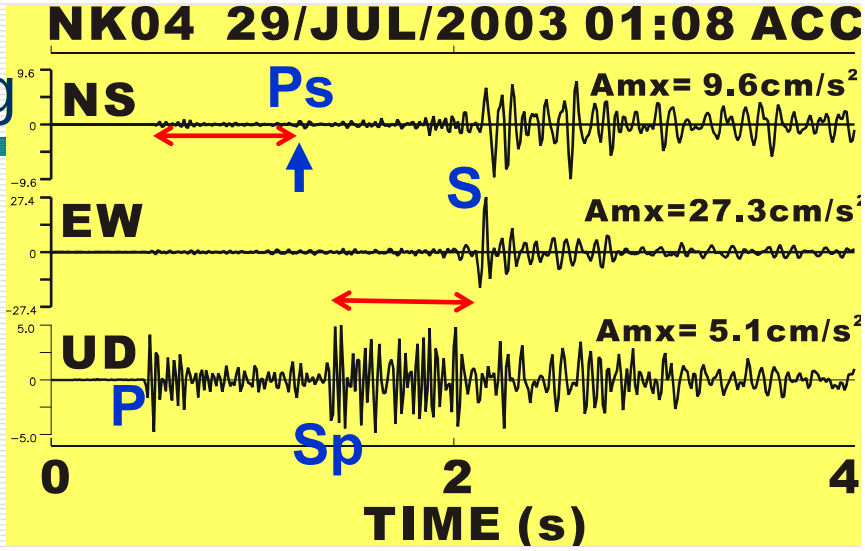
Seismic Observation

- Seismic observation is also carried out to examine the effect of surface soils by using the array of sensors in Lima city.

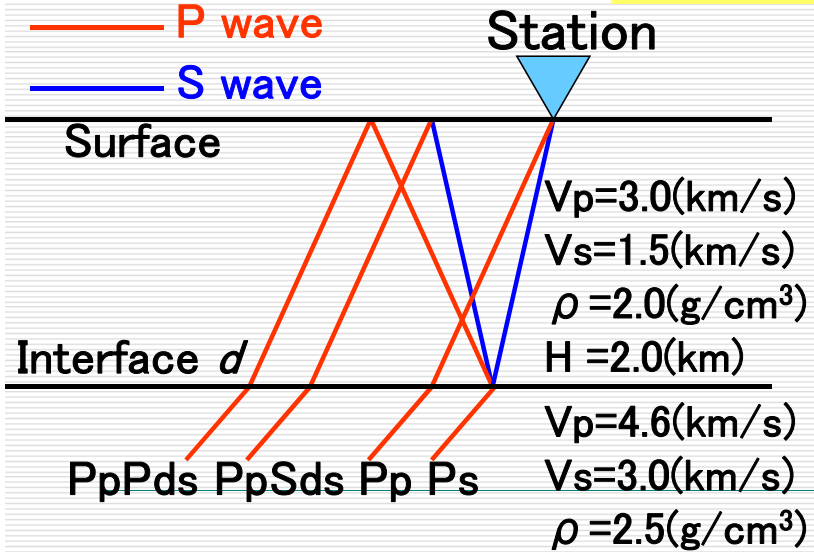
Seismometer



Use of Converted Wave for Vs-profiling



Many later phases can be seen between initial P- and S-waves.



Initial P-wave generates P- and S-waves at each interface. The P- and S-waves at surface appear in vertical and radial components. These data are used to obtain deep Vs profile.

Research Plans of SM/GT Group

- Fault models for large scenario earthquakes along the subducting plate with cooperation of Tsunami group.
- Installation of strong motion instruments on ground or BF of buildings (5 locations in Lima at first)
- Geophysical and geotechnical surveys for shallow and deep S-wave structure including borehole loggings
- Analysis of earthquake data from small events to characterize source, path and site amplification
- Calculation of site amplifications for microzonation map

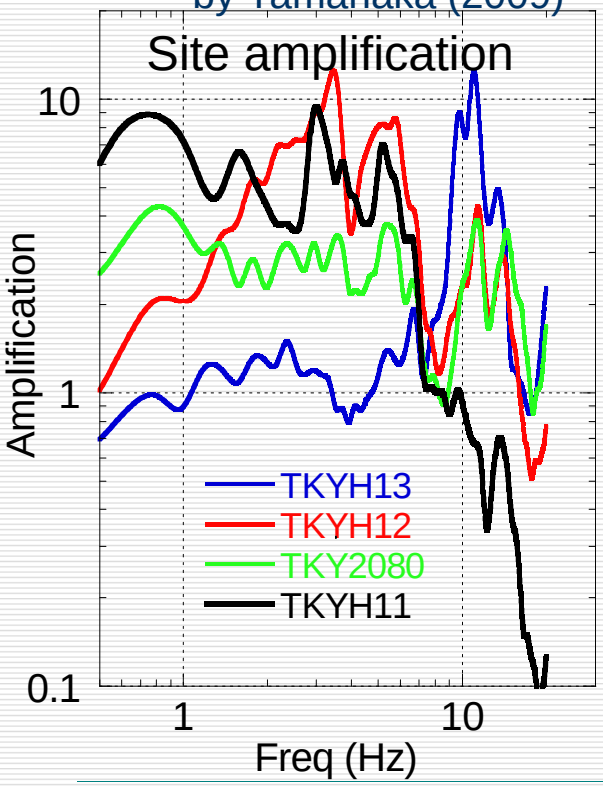
- Estimation of slope failure from geotechnical surveys
- Strong motion simulation based on hybrid approach of theoretical and empirical methods

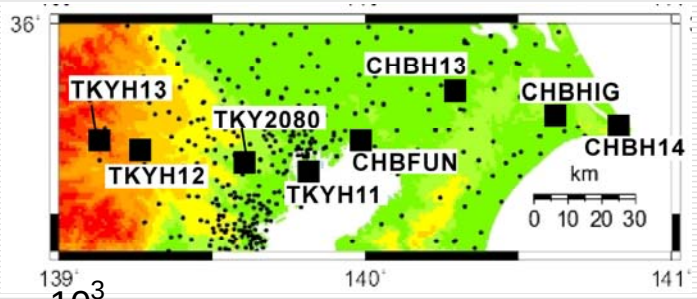
Analysis of Small Earthquake Data

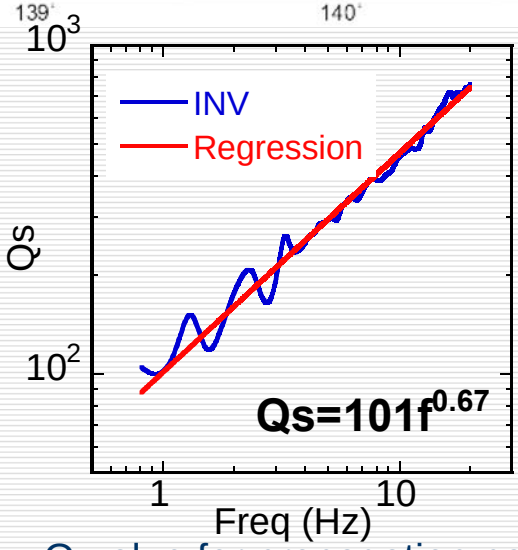
- Estimation of source characteristics of small events, Q-factor for the crust and mantle, site amplification
- Estimation of envelope function of small events for use of stochastic Green's function
- Exploration of deep S-wave velocity profiles using earthquake data, such as receiver function, phase velocity and Rayleigh wave ellipticity
- Validation of geological models from geophysical and geotechnical surveys using 1D site amplification or 3D simulation of moderate events
- Examination of applicability of existing attenuation equations

Estimation of Empirical Site Amplification from from Earthquake Data

Case for Tokyo area
by Yamanaka (2009)



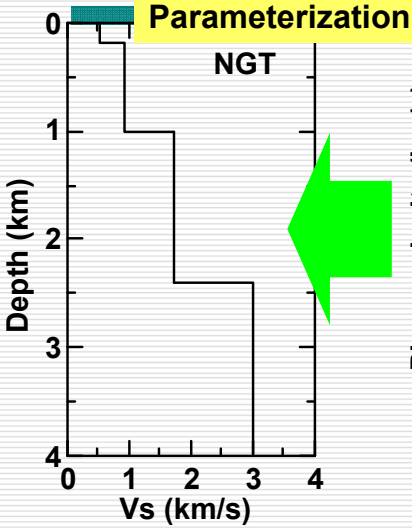




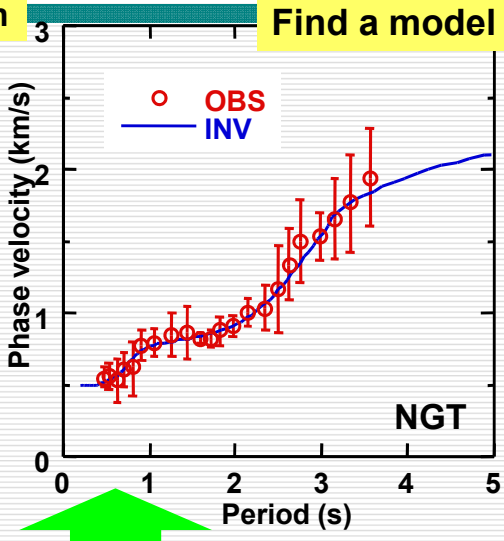
Q-value for propagation path in crust and mantle

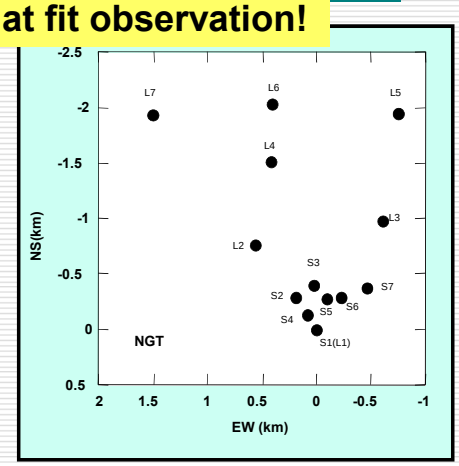
Inversion of Rayleigh Wave Phase Velocity for Exploration of Deep Vs Profile

Parameterization

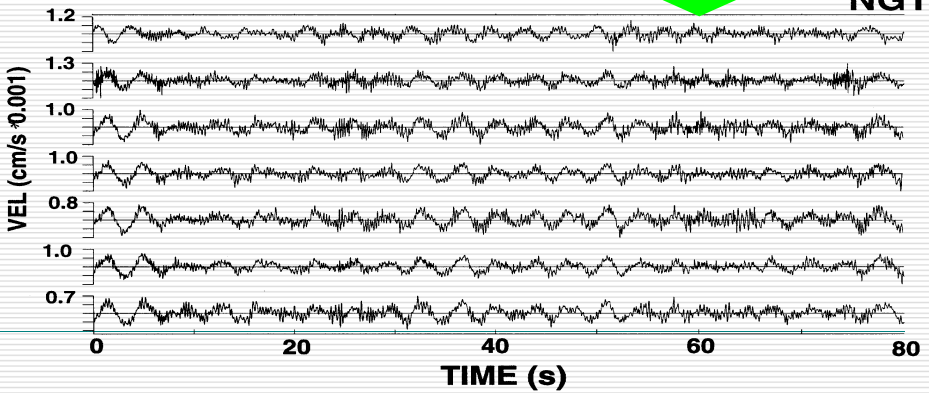


Find a model that fit observation!



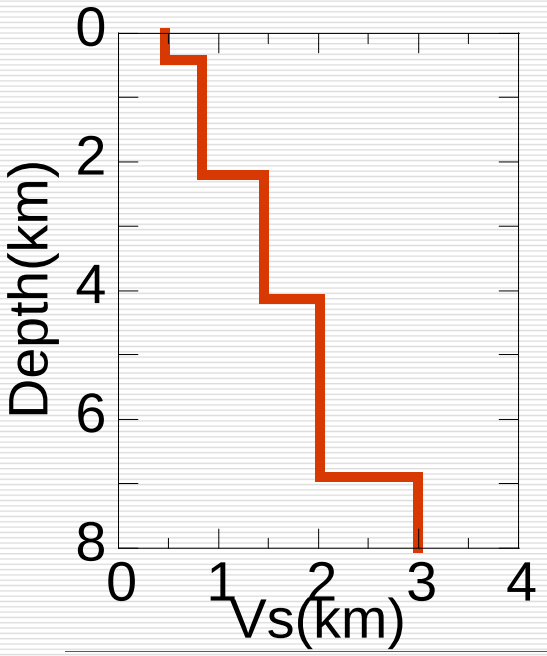


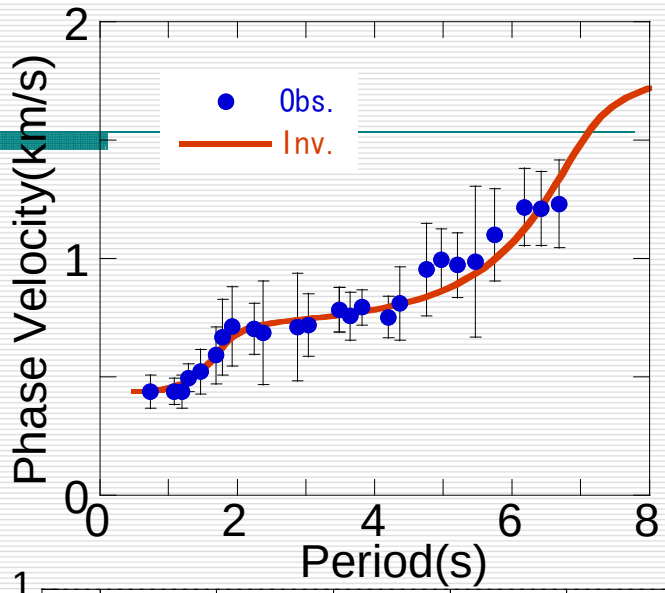
Estimation of amplification with numerical simulation

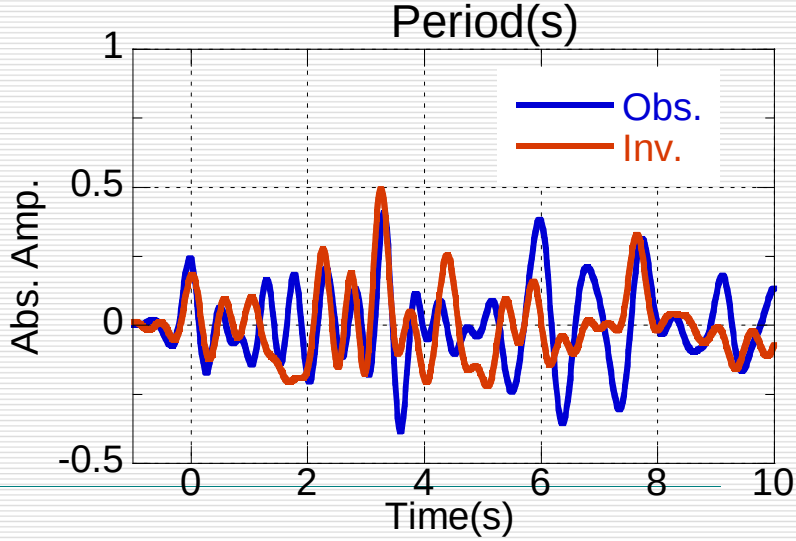


Joint Inversion of Phase Velocity and Receiver Function

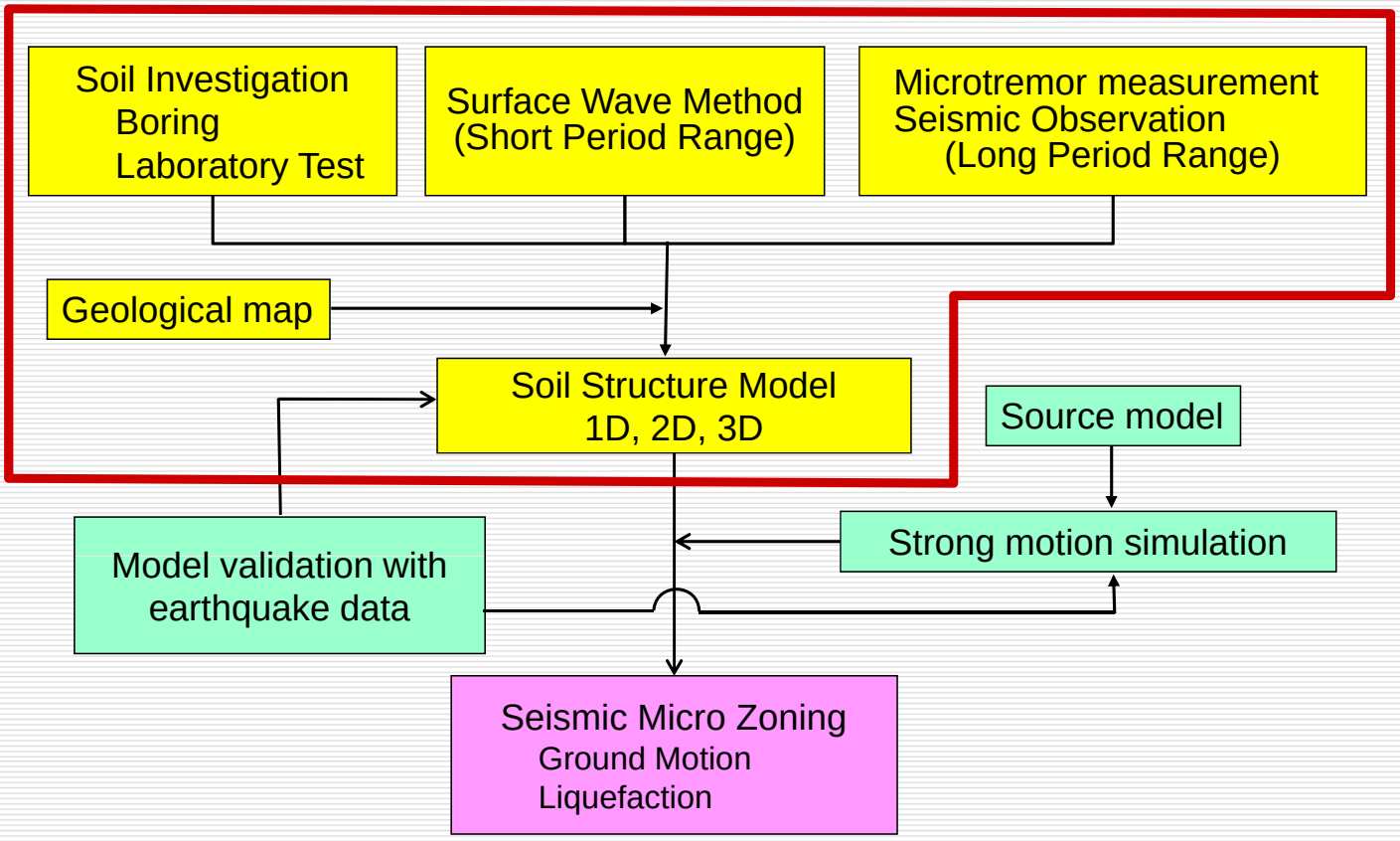
(Kurose and Yamanaka, 2006)





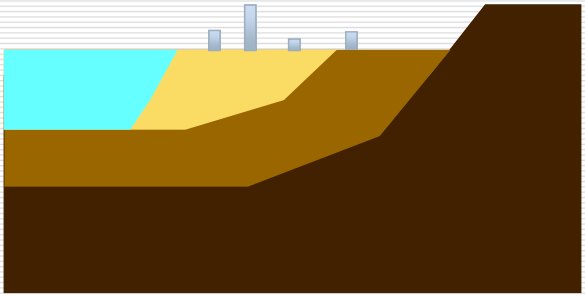


Geophysical & Geotechnical surveys

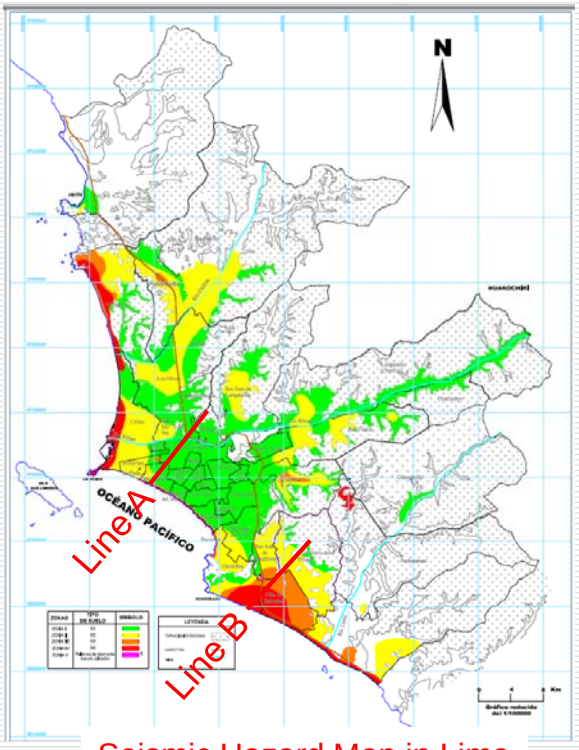


Seismic Micro Zoning

- Seismic Micro Zoning will be improved based on various in-depth surveys.
- 2 or 3-Dimensional soil structure model will be constructed.



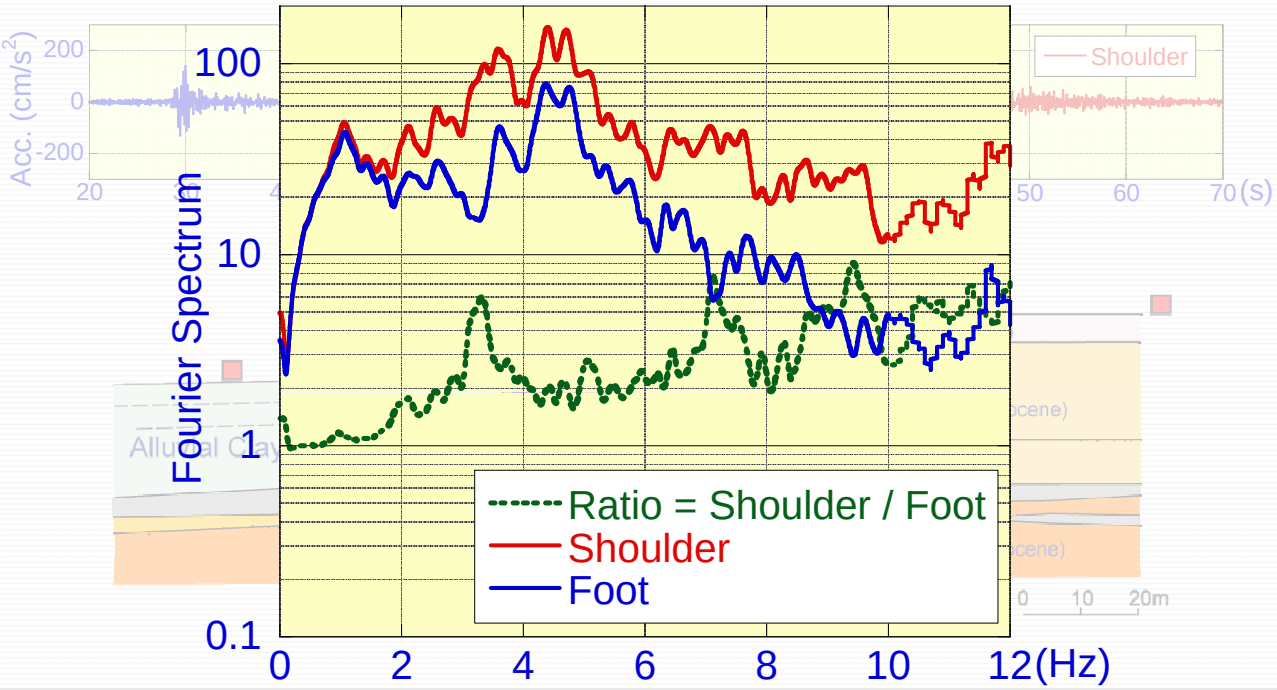
2-Dimensional Soil Structure Model



Seismic Hazard Map in Lima (CISMID)

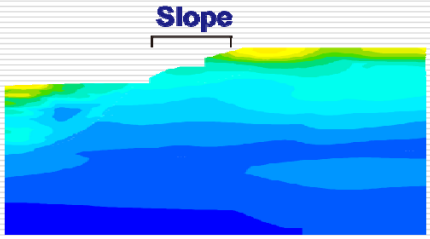
Seismic Risk of Slopes (2)

- It is known that the response due to an earthquake tends to become large at the shoulder of a slope.

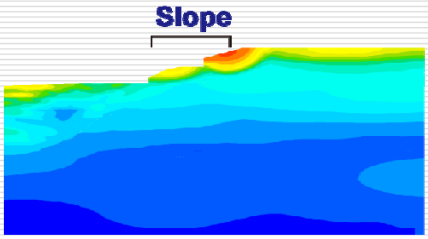


Seismic Risk of Slopes (3)

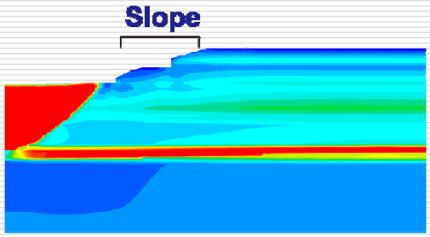
- One of the reasons is believed that the surface soil of a slope is “weakened” due to weathering.
- The existence of this weakened soil has a negative influence to the seismic risk from various aspects.



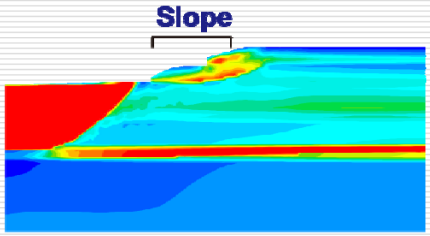
Acceleration due to EQ (without weakened soil)



Acceleration due to EQ (with weakened soil)



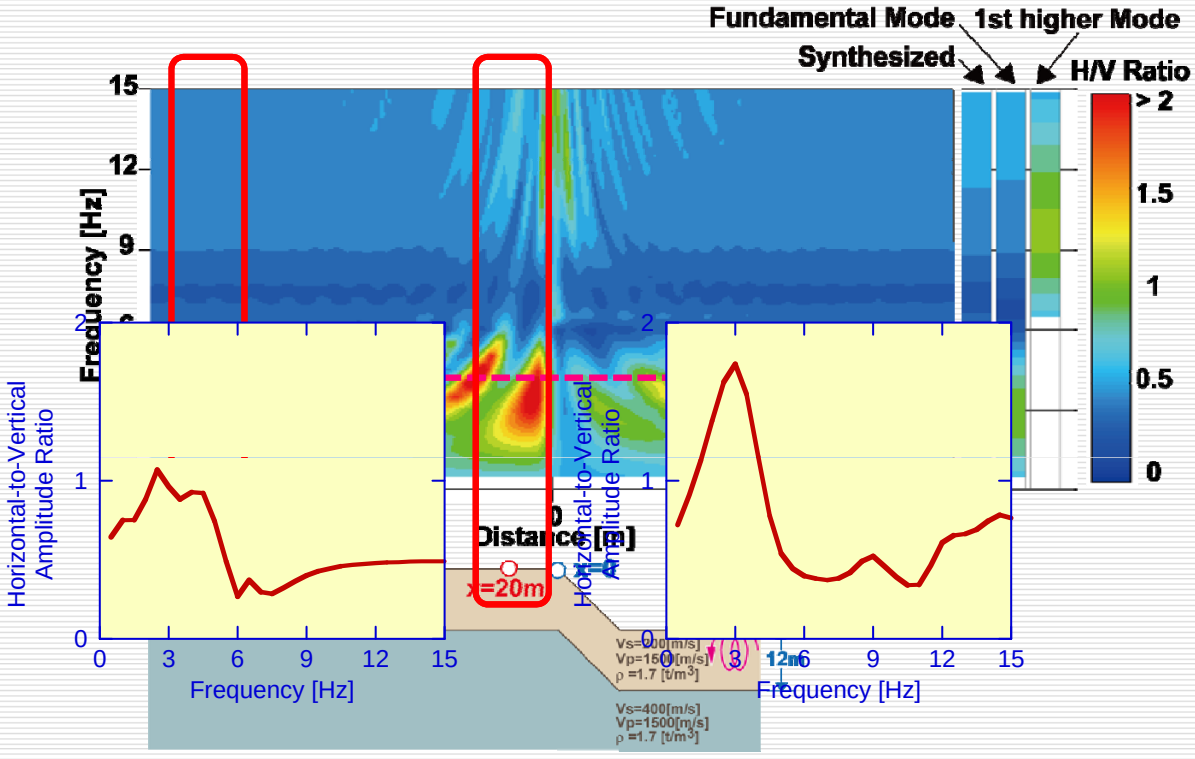
Shear strain due to EQ (without weakened soil)



Shear strain due to EQ (with weakened soil)

H/V Spectral Ratio

- This is another example of the effect of a slope. The results of microtremor measurement are also affected by the slope.



Research Plan for Evaluation of Risk of Slopes

- The research plan includes:
  - Select a few target sites in Lima, where houses are densely built.
  - Collect soil investigation data, if any.
  - Conduct soil investigation, if possible.
  - Conduct a series of microtremor measurements.
  - Construct soil models and perform finite element analyses.
  - Evaluate seismic risks of the area with slopes based on these data along with the results from other groups in this project.