

**GSI 1st Workshop of Asia-Pacific Region Global Earthquake and
Volcanic Eruption Risk Management
Tsukuba, Japan, Feb, 22-25, 2012**

**EARTHQUAKE AND TSUNAMI HAZARD
ASSESSMENT IN COASTAL AREAS OF VIETNAM
AND MEASURES FOR SEISMIC RISK MITIGATION**

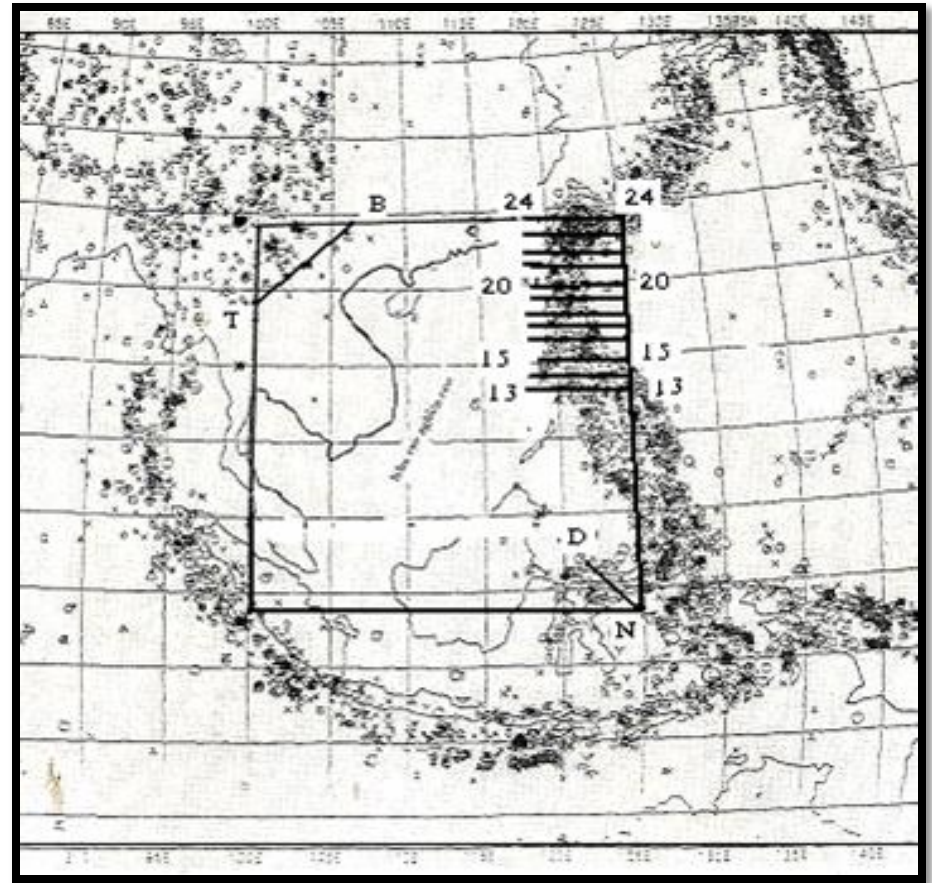
**Bui Cong Que and Nguyen Hong Phuong
Institute of Geophysics
Vietnam Academy of Science and Technology**

CONTENTS

- Introduction
- Seismicity and seismotectonics
- Earthquake hazard evaluation
- Identification of Tsunami source zones
- Tsunami affects evaluation
- Measures for Earthquake and Tsunami hazard mitigation
- Vietnam National System for Earthquake information and Tsunami warning
- Conclusion

COASTAL AREAS OF VIETNAM

- Coastline length: 3260km, 2600 Islands
- 4 main coastal area: North-Northeastern, Central, Southeastern and Southwestern areas
- Population: 20 millions
- Big cities: Halong, Haiphong, Danang, Nhatrang, Vungtau.
- 12 industrial zones, 18 big ports, 25 tourism zones



Study area and seismicity
of southeast region

MAIN RESEARCH PROJECTS ON EARTHQUAKE AND TSUNAMI HAZARD ASSESSMENT IN VIETNAM

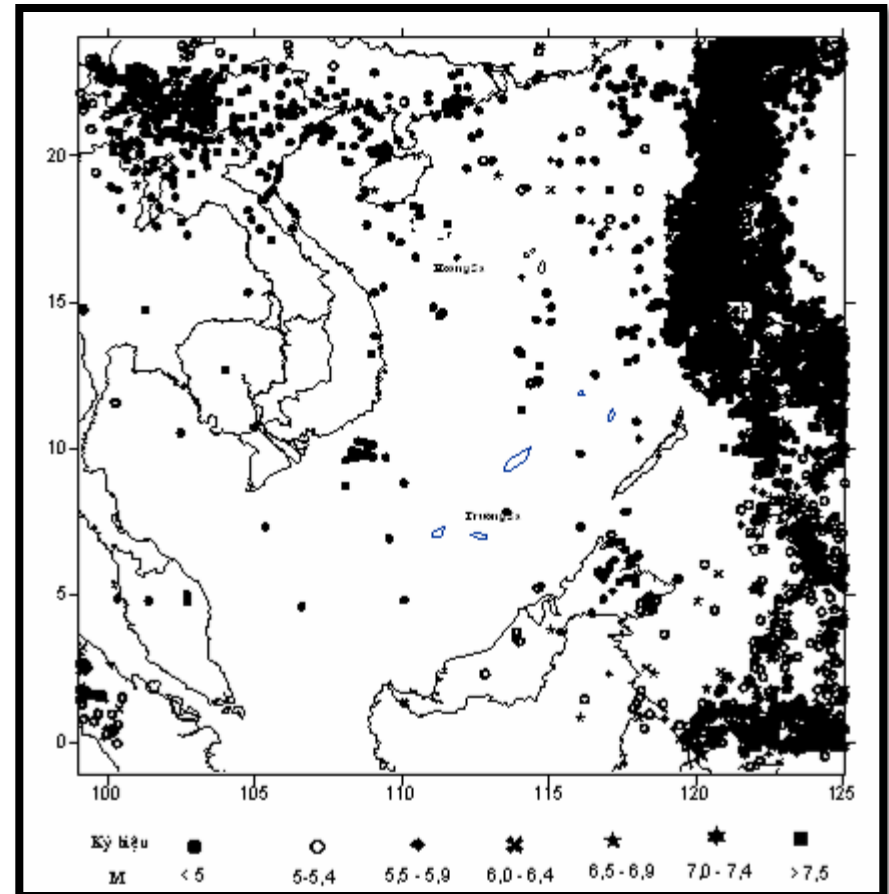
- Study of Earthquake and Tsunami hazard in Coastal area of Vietnam, Vietnam Academy of Science and technology, Nguyen Dinh Xuyen (2005 - 2006)
- Evaluation of Tsunami hazard in coastal zone of Vietnam. Vietnam Academy of Science and technology. Tran Thi My Thanh (2006 - 2007)
- Numerical Modeling for possible Tsunami scenarios affecting coastal areas of Vietnam. Ministry of Environment and resources. Vu Thanh Ca (2007 - 2008)
- Tsunami Hazard and Risk assessment and preparedness for Vietnam. Vietnam – New Zealand Cooperation project. Bui Cong Que, IGP and Terry Webb, GNS, (2007 - 2009)
- Study of Earthquake and Tsunami Hazard assessment in Coastal areas of Vietnam and mitigation measures. Vietnam National Research project. Bui Cong Que, (2007 – 2010)

STUDY OF SEISMICITY AND SEISMOTECTONICS

- Seismicity of Vietnam and Eastern sea
- Seismicity of Southeast Asia region
- Seismotectonics of Vietnam
- Geodynamic and recent tectonic movement
- Study of active tectonic faults
- Study of volcanic and landslide activities in the offshore areas

SESMICITY OF VIETNAM AND EASTERN SEA

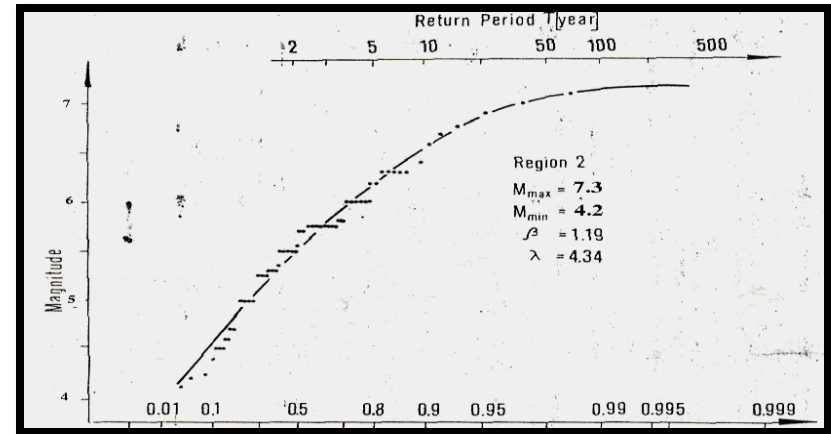
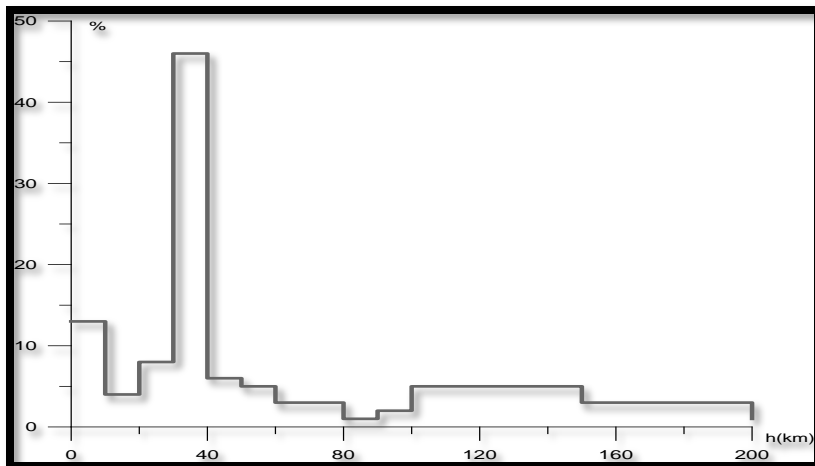
- Catalog of Earthquake with:
 - + $M \geq 5$ on data of ISC (1900-2008)
 - + $M \geq 3$ on data of local seismic network and historic data.
- Study area: 1° N - 24° N, 99° E - 125° E.
- Total 8955 Earthquakes with:
 - + 2086 $\sim M = 5 - 5,9$
 - + 331 $\sim M = 6 - 6,9$
 - + 78 $\sim M = 7 - 7,9$
 - + 10 $\sim M \geq 8$



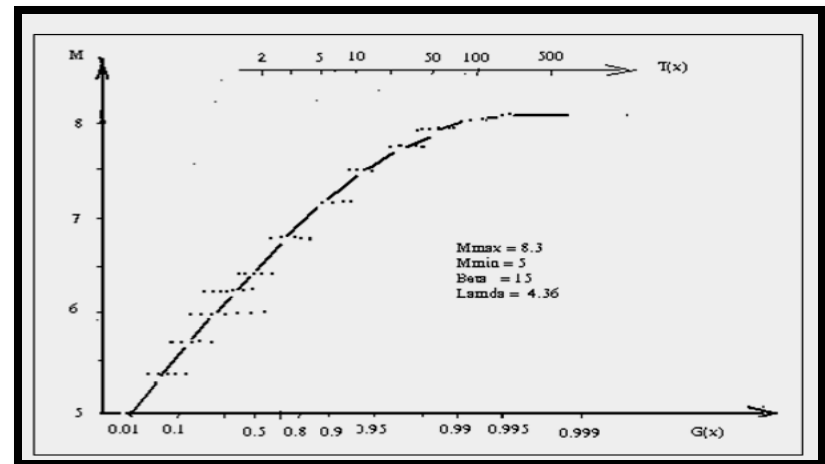
Distribution of epicenters
in Vietnam and Eastern Sea

SESMICITY OF VIETNAM AND EASTERN SEA

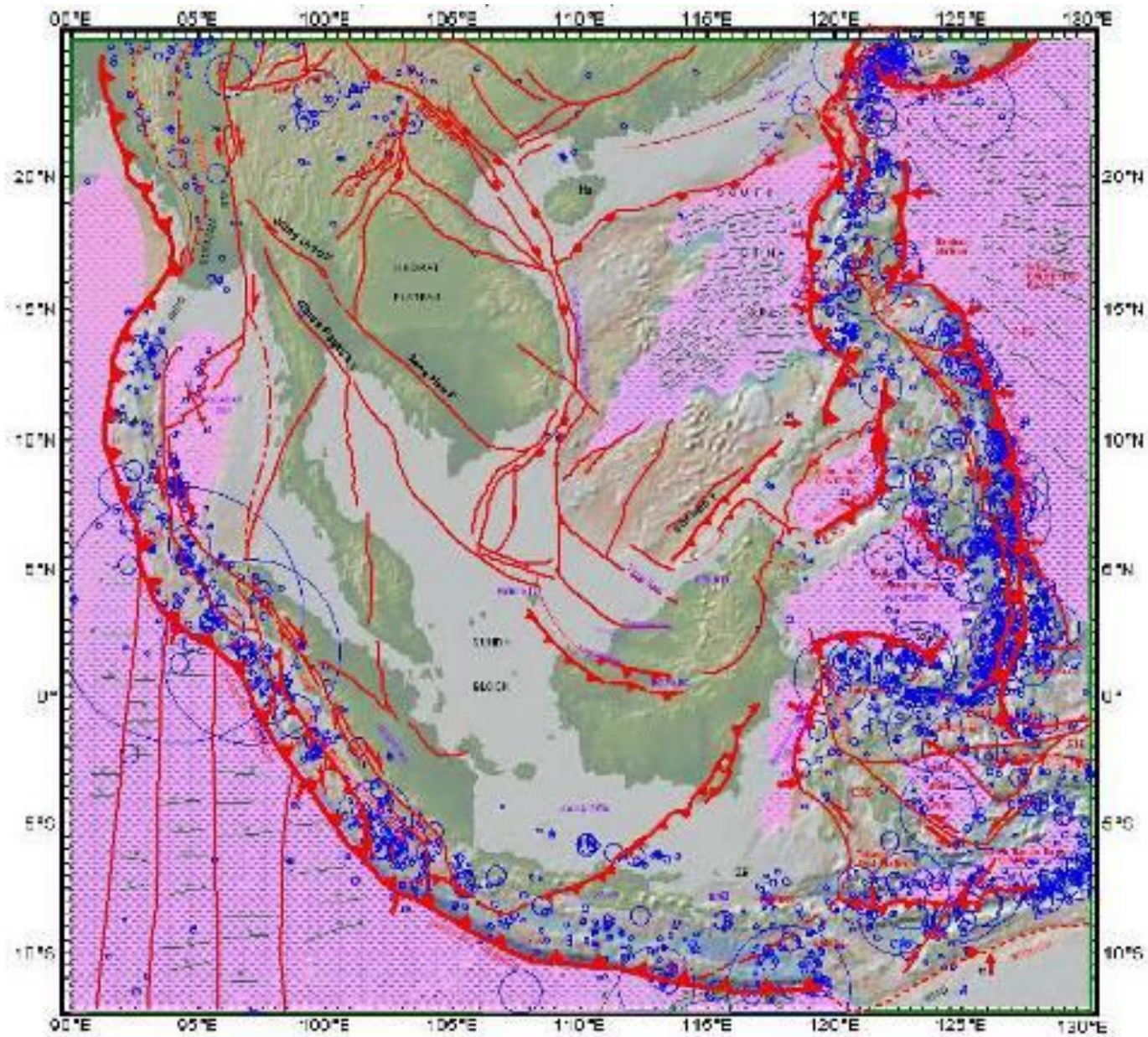
- Maximum Earthquake evaluation
+ Earthquake energy estimation:
 $\log E = 11,8 + 1,5M$
- Distribution of epicenters on the Depth:



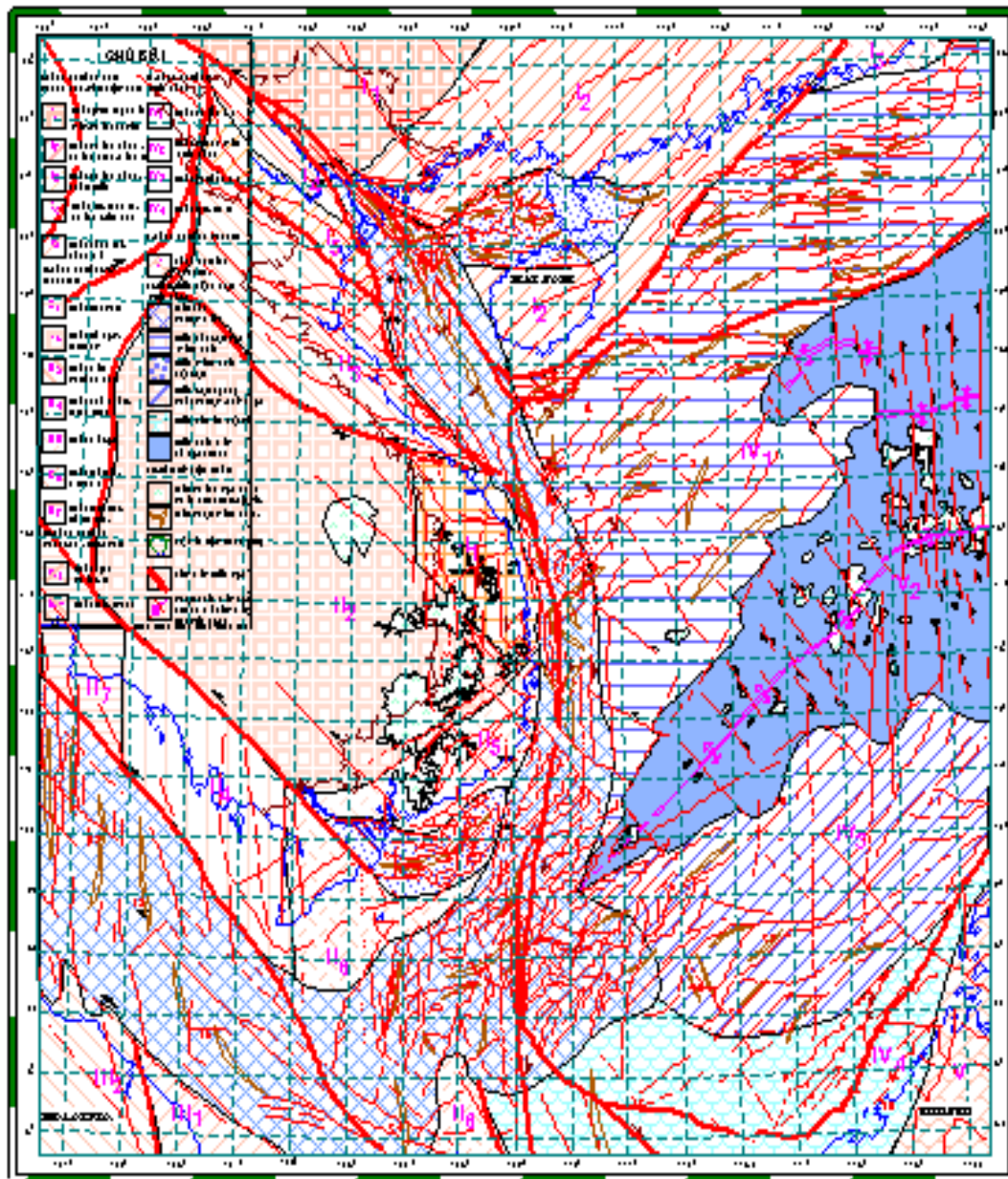
Mmax for Vietnam territory



Mmax for Eastern Sea of Vietnam



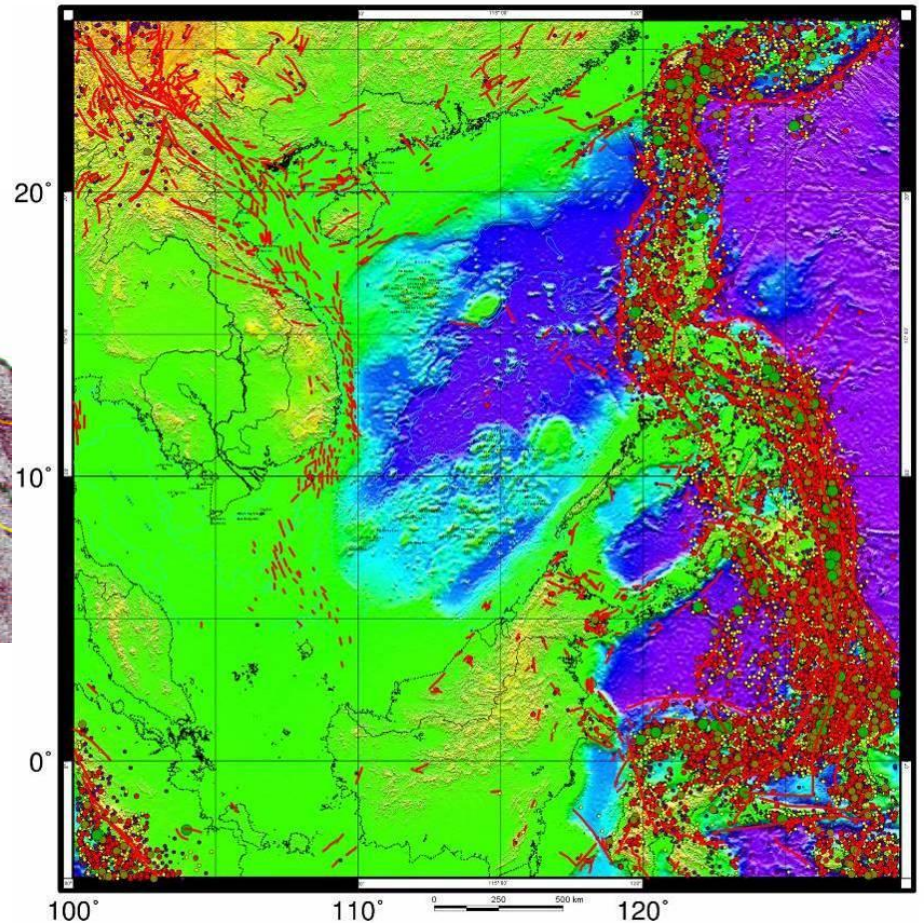
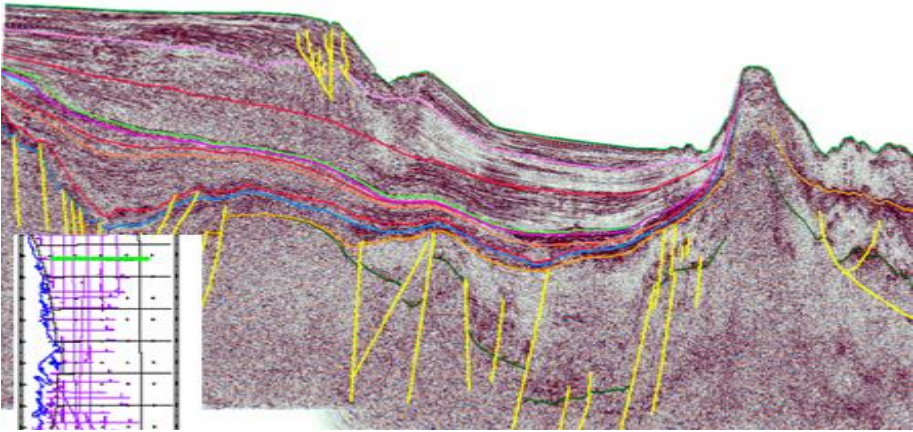
Seismotectonic scheme of Southeast Asia region



Structural and Tectonic Map
in Vietnam and adjacent areas

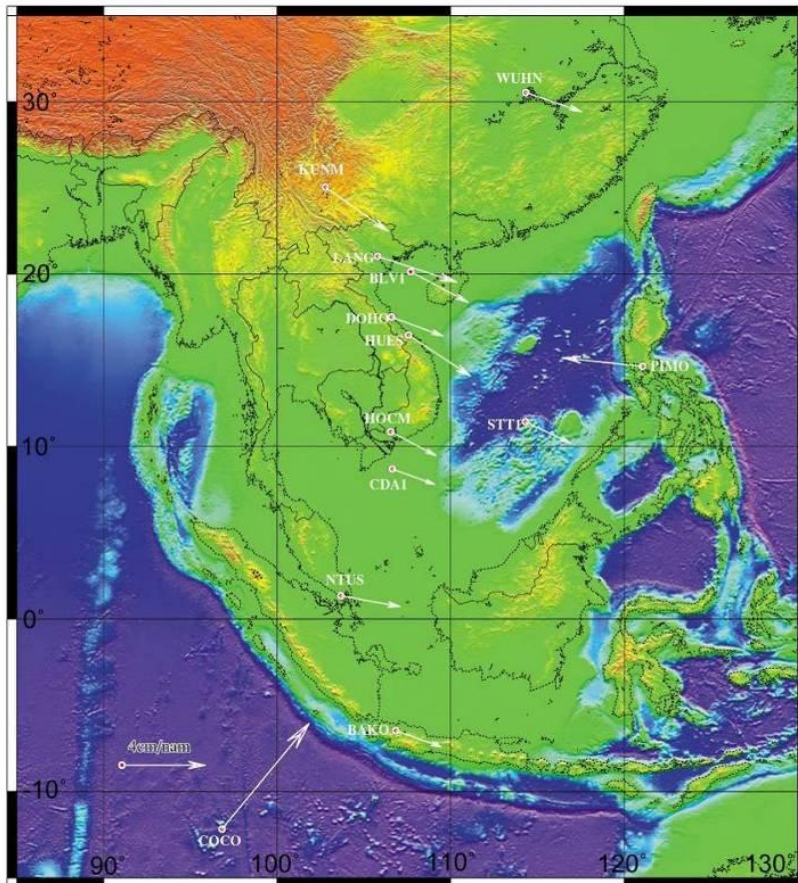
STUDY OF GEODYNAMICS AND RECENT TECTONIC MOVEMENT

- Study of the active faults in Pliocene – quaternary sediment

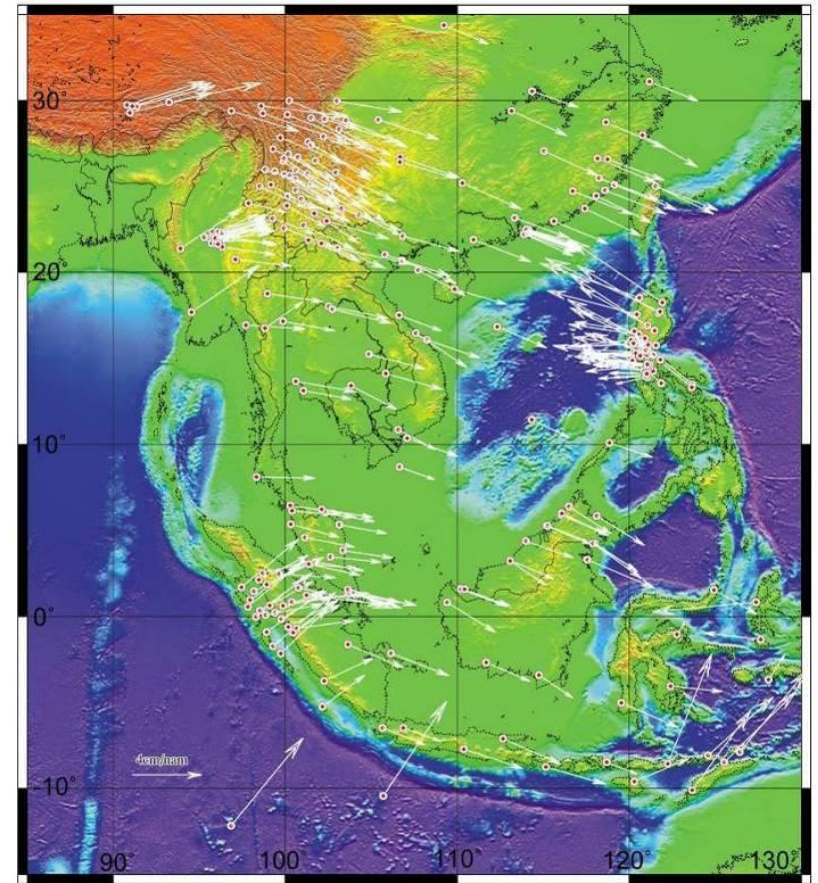


STUDY OF GEODYNAMICS AND RECENT TECTONIC MOVEMENT

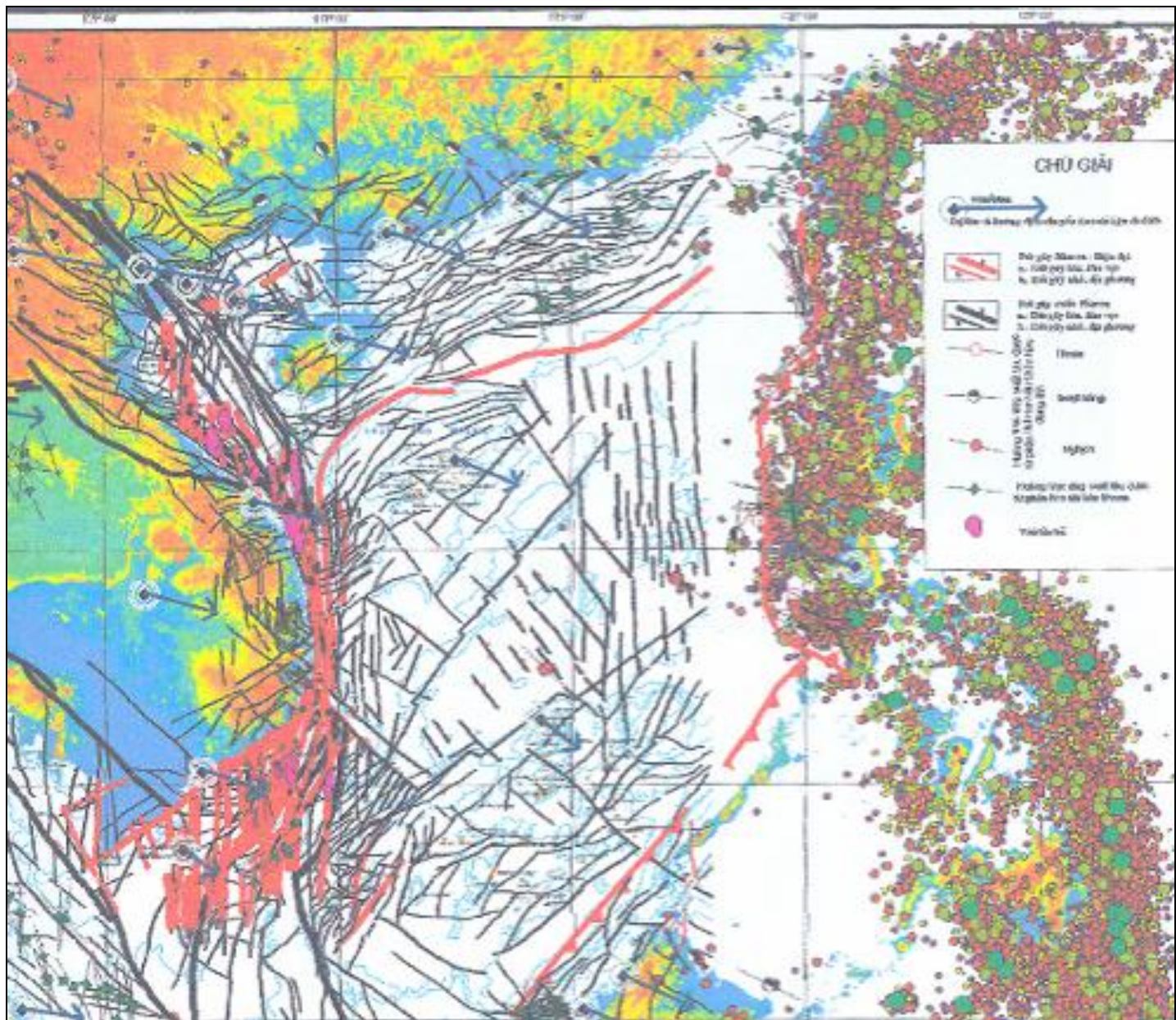
- Study of recent tectonic movement on GPS network



Crustal motion
for 2007, 2008, 2009



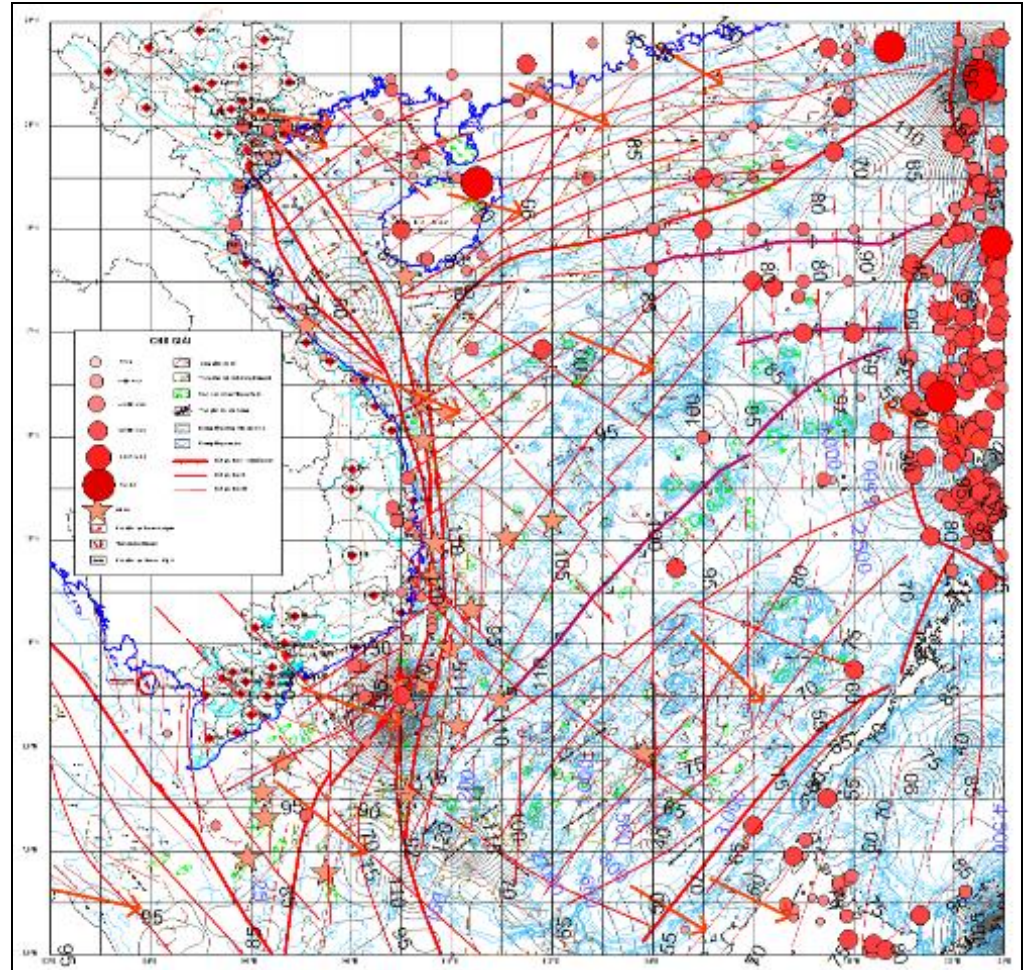
Crustal motion on the Projects
GEODYSSEA, PCGIAP, SEAMERGES



Scheme of geodynamics and modern tectonic movements

SCHEME OF ACTIVE TECTONIC FAULTS

- Data of gravity and magnetic anomalies
- Seismic profiling data of high resolution
- Data of seismicity
- Data of volcanic activities



EARTHQUAKE HAZARD ASSESSMENT

Method

- Probabilistic approach: Cornell A.C. method (1968)
- Seismic hazard is calculated by

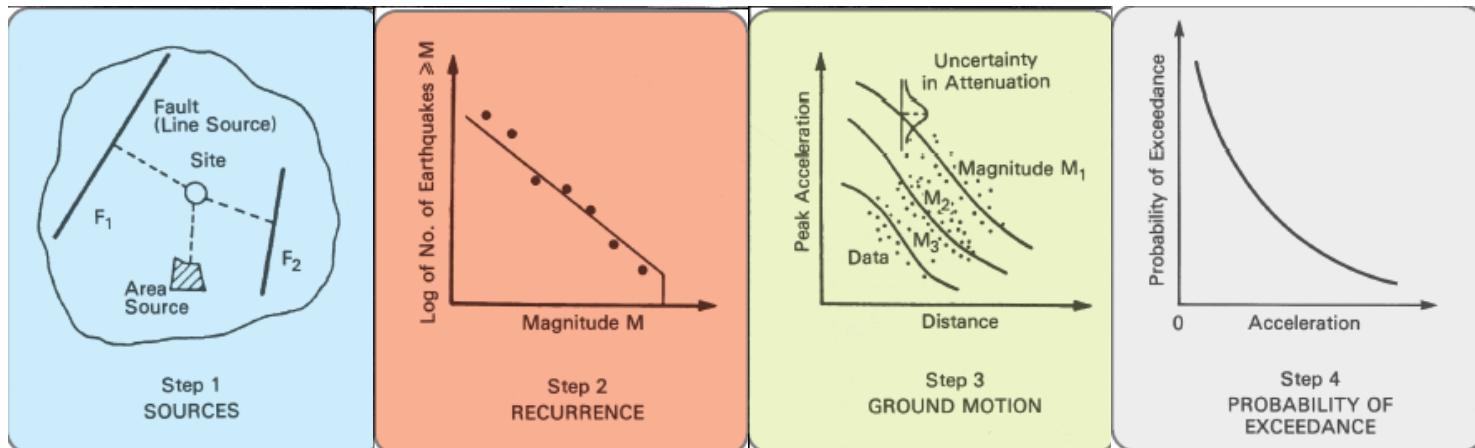
$$P[A] = \int_r \int_M P[A|M, r] f_M(m) f_R(r) dM dr$$

where P indicates probability, A is the event whose probability is sought, and m and r are continuous, independent random variables which influence A . In our case, A represents the event that a specific value of ground motion intensity is exceeded at the site of interest during an earthquake, variables m and r represent earthquake size (magnitude) and distance from the site of interest.

EARTHQUAKE HAZARD ASSESSMENT

Procedure

1. Determination of seismic source zones in the study area;
2. Estimation of earthquake hazard parameters for each source zone
3. Choosing an attenuation equation for the study area;
4. Seismic Hazard computation and mapping.



EARTHQUAKE HAZARD ASSESSMENT

Tools

1. EQRISK program by McGuire (1974)
2. program by

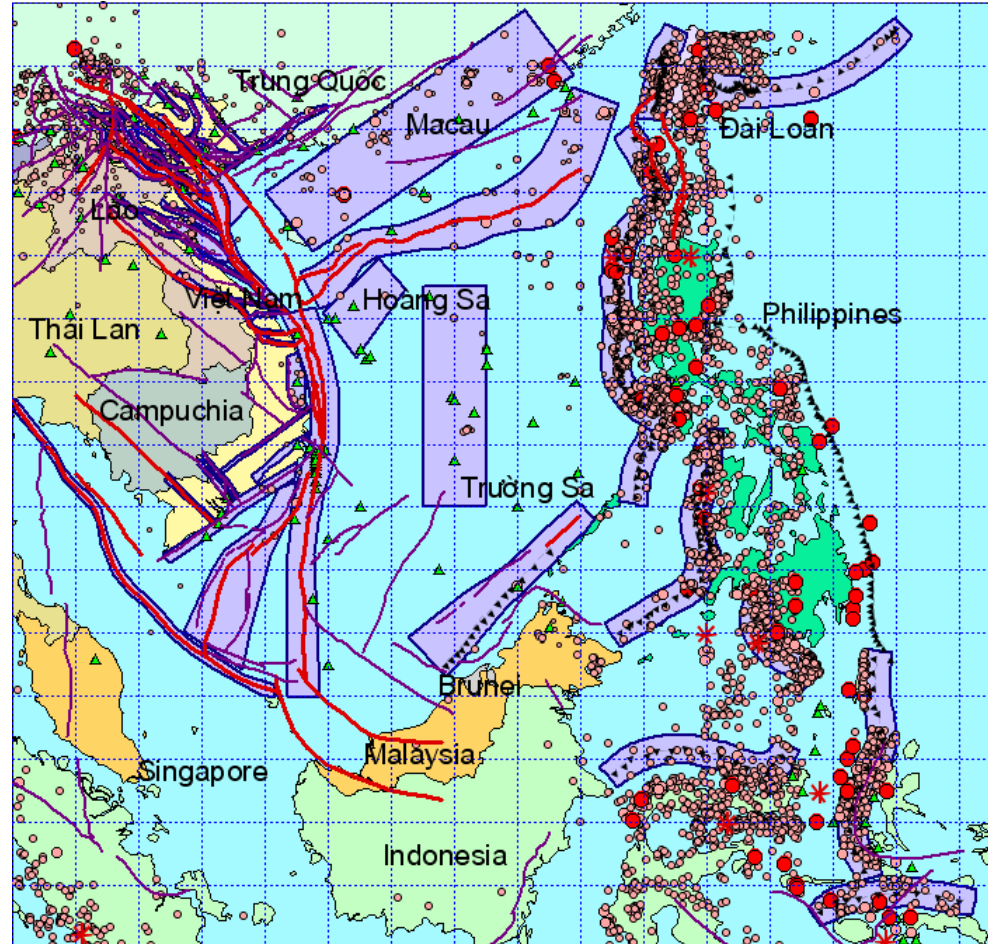
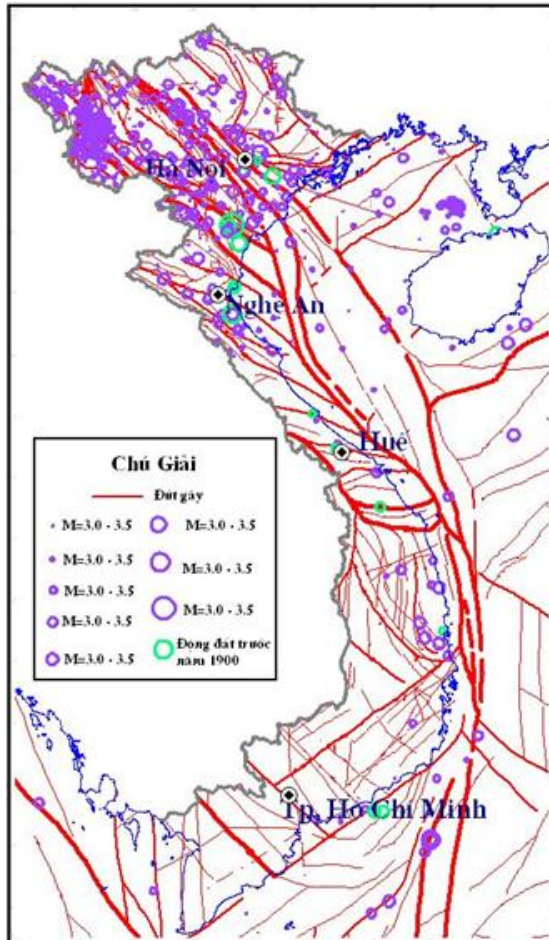
EARTHQUAKE HAZARD ASSESSMENT

Input Data

- An Earthquake catalog of Vietnam and adjacent sea areas for the period from 114 to 2008 including 3197 events, compiled by the Institute of Geophysics, VAST. The catalog incorporates all historical as well as instrumental data collected from various sources (*ISC, USGS, NEIS, BEJ*).

EARTHQUAKE HAZARD ASSESSMENT

Input Data



EARTHQUAKE HAZARD ASSESSMENT

Parameter estimation

The following earthquake hazard parameters, characterizing level of seismicity, were estimated for all seismic source zones in the territory of Vietnam and adjacent sea areas:

- Expected maximum magnitude M_{max} ;
- Constants a , b in the Gutenberg-Richter magnitude-frequency relation and their deductive values α and β ;
- Mean return period $T(M)$ of the strong earthquakes with magnitude M .

EARTHQUAKE HAZARD ASSESSMENT

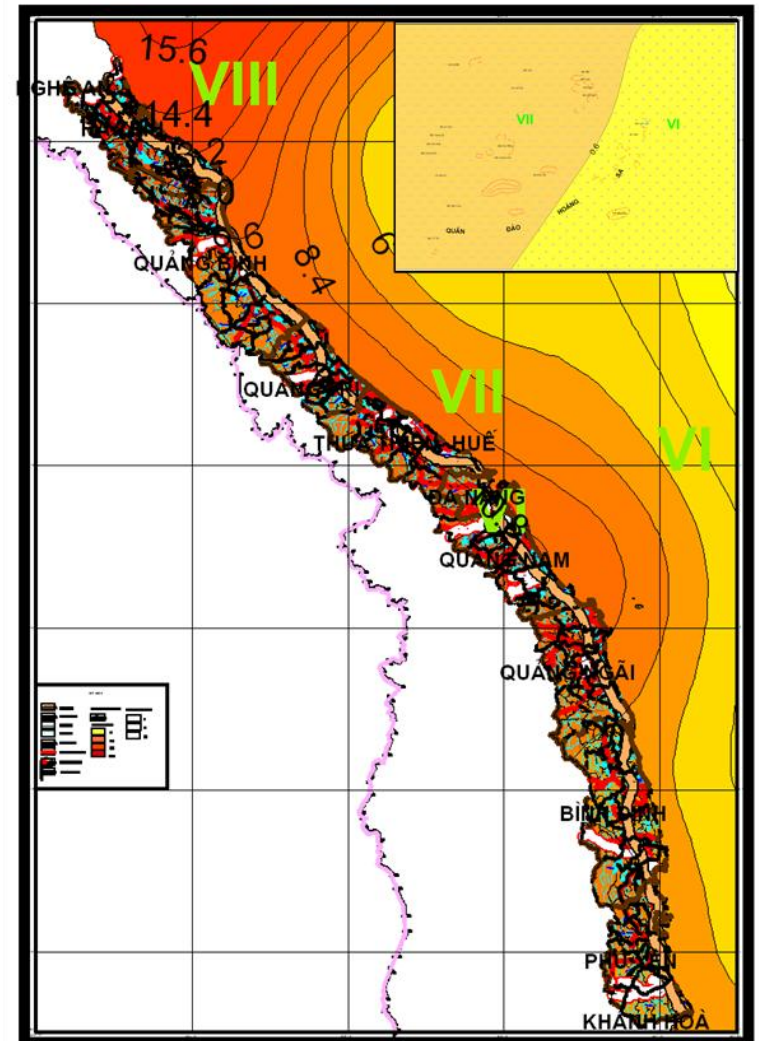
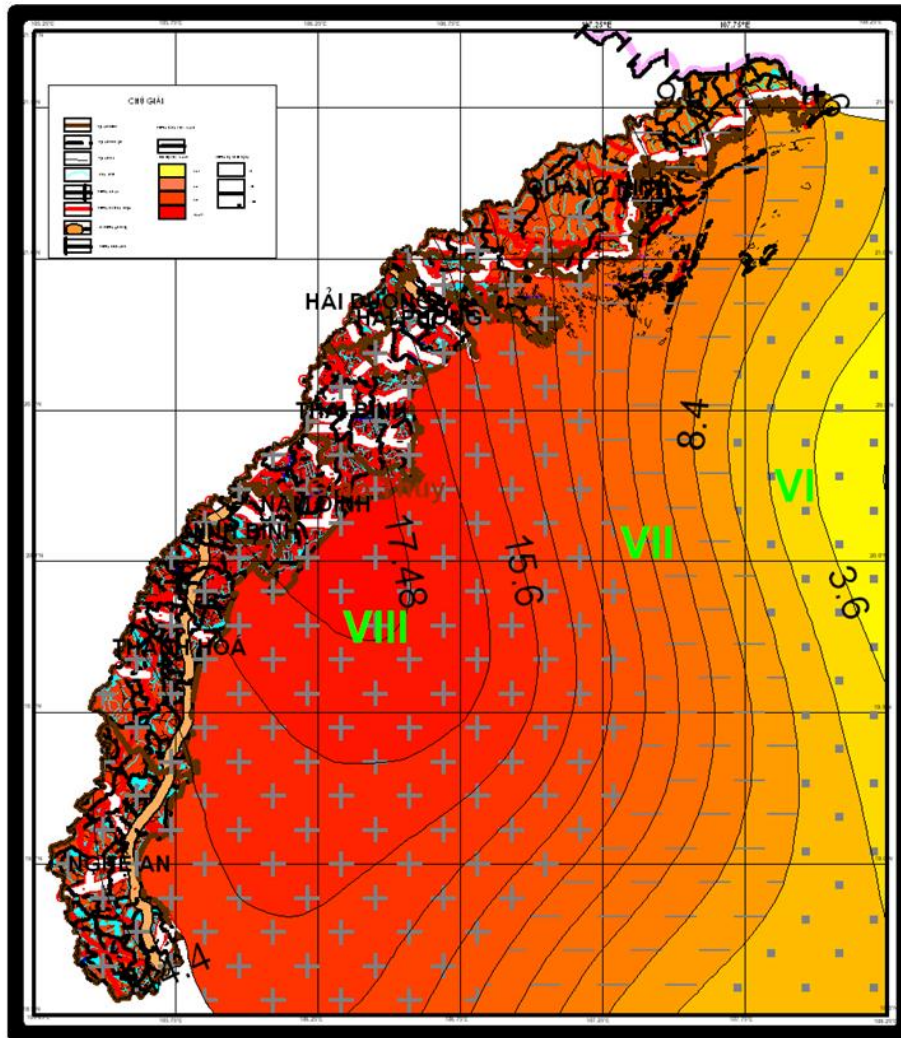
Attenuation relationship

The Campbell (1997) attenuation relationship was chosen for application:

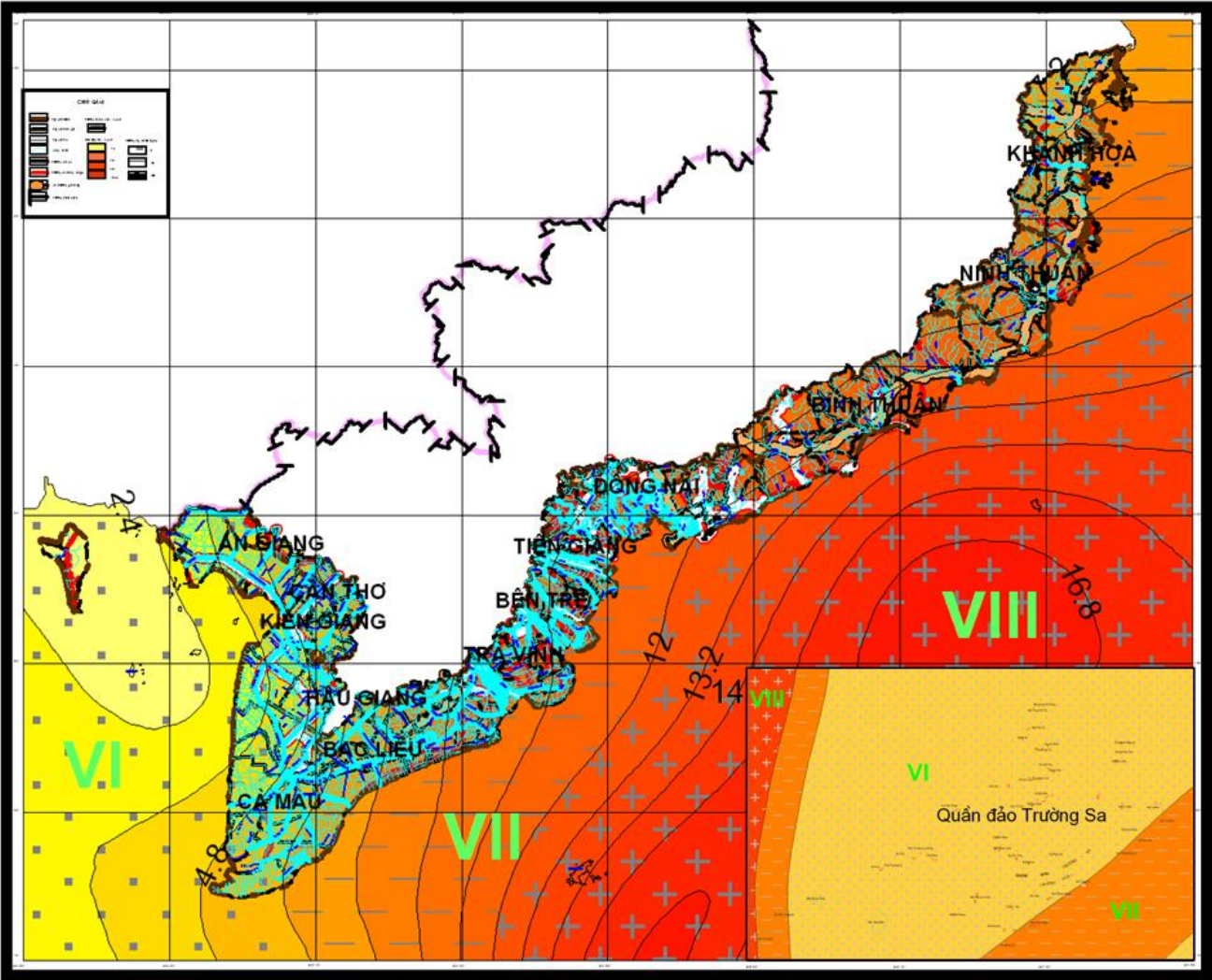
$$\ln(A_H) = -3.512 + 0.904 M_w - 1.328 \ln\{R_{SEI}^2 + [0.149 \exp(0.647 M_w)]^2\} \\ + [1.125 - 0.112 \ln(R_{SEI}) - 0.0957 M_w] F + [0.440 - 0.171 \ln(R_{SEI})] SSR \\ + [0.405 - 0.222 \ln(R_{SEI})] SHR + \sigma$$

where: A_H is horizontal PGA, in g ($g = 981 \text{ cm/s}^2$). R_{seis} is the closest distance from the site to the zone of the seismogenic rupture, M_w is the moment magnitude of the earthquake, F is a fault type flag: $GRS = 1$ for reverse-slip faults, 0 otherwise, SSR and SHR are site coefficients: for soft soils $SSR = SHR = 0$; $SSR = 1$, $SHR = 0$ for soft rocks; $SSR = 0$, $SHR = 1$ for hard rock and σ is the standard deviation, with $\sigma = 0.4095$.

MAP OF EARTHQUAKE HAZARD IN NORTH AND CENTRAL COASTAL AREAS OF VIETNAM. RETURN PERIOD 950 YEARS, SITE A

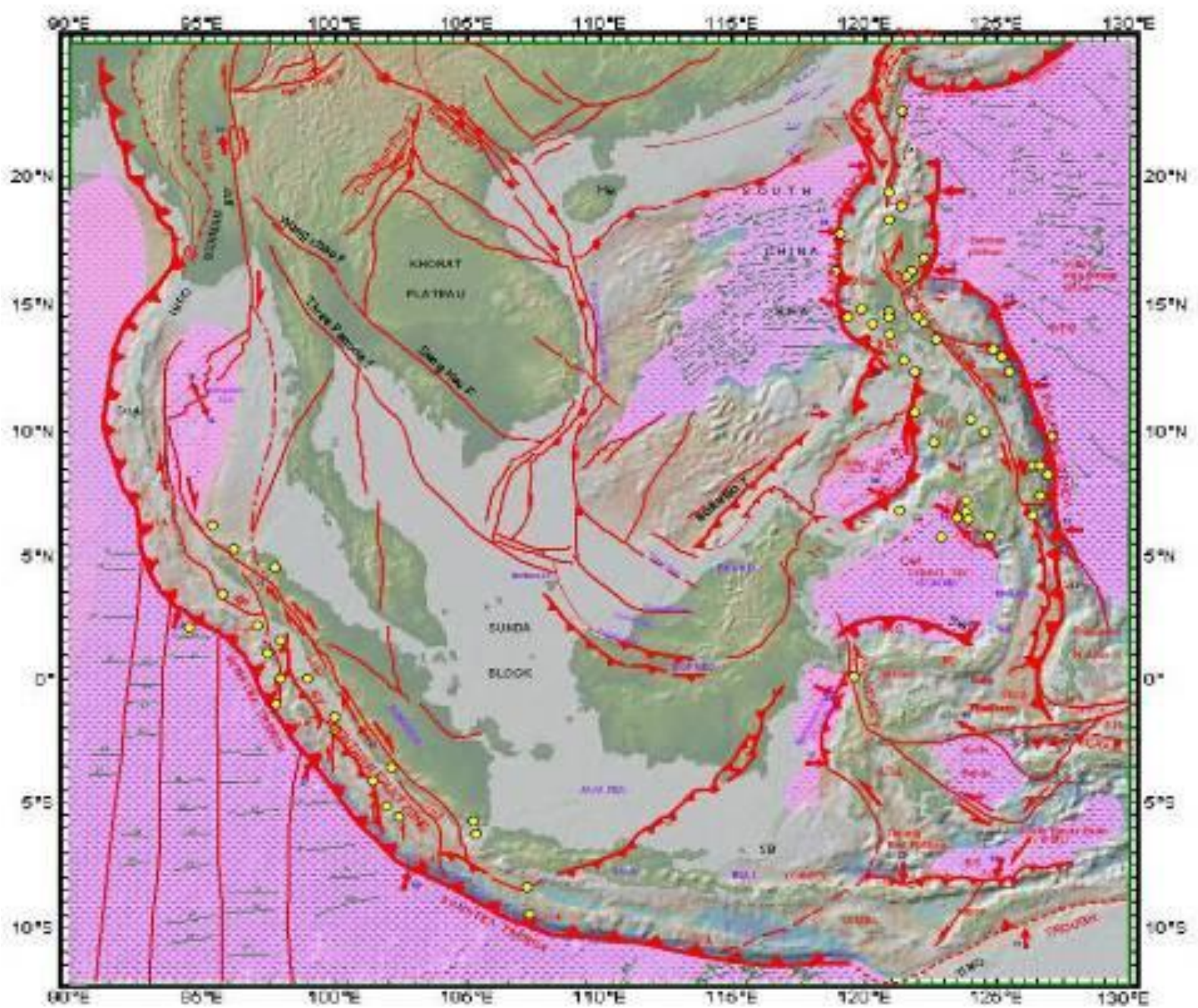


MAP OF EARTHQUAKE HAZARD IN SOUTHERN COASTAL AREAS OF VIETNAM. RETURN PERIOD 950 YEARS, SITE A

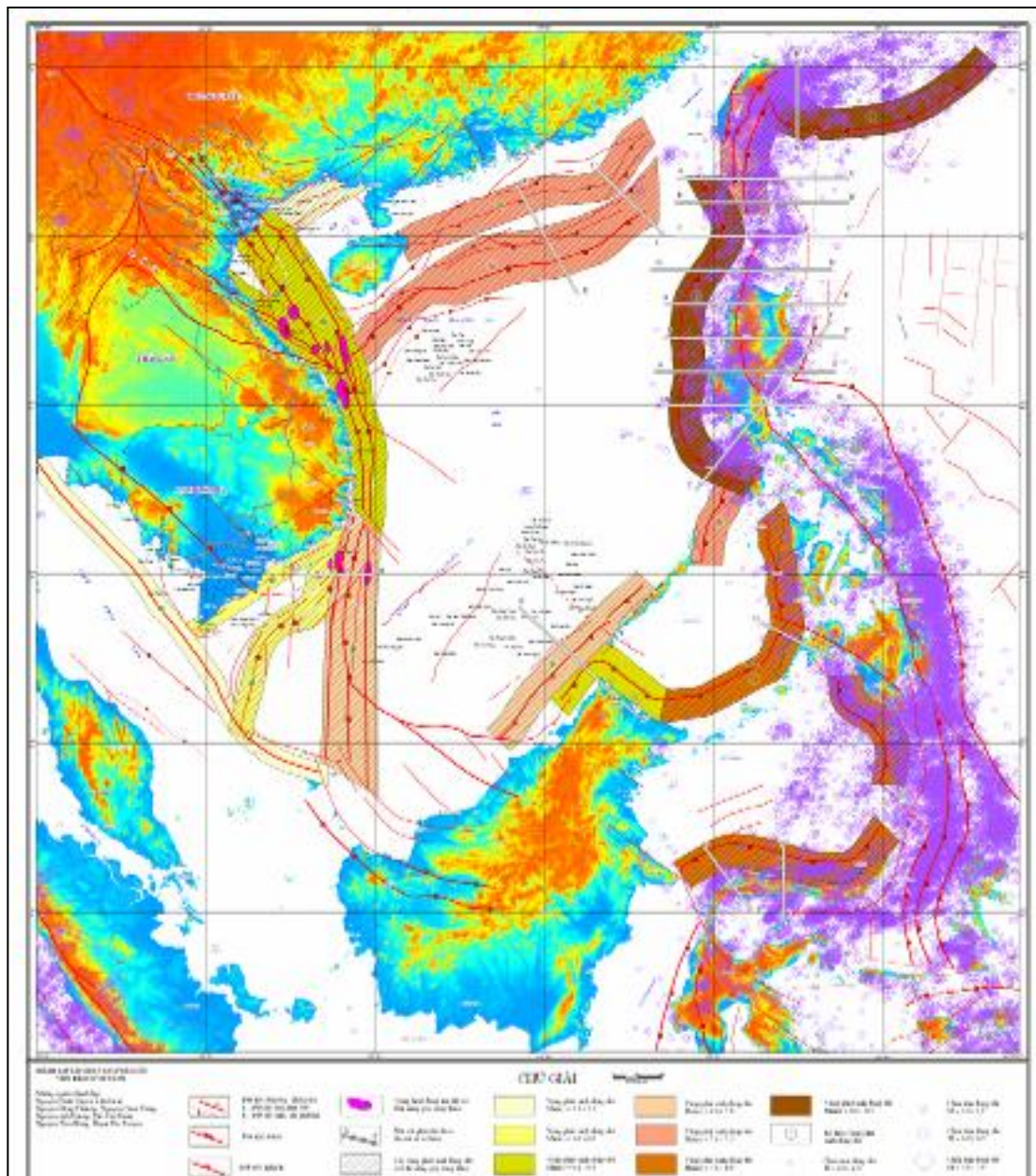


IDENTIFICATION OF TSUNAMI SOURCE ZONES

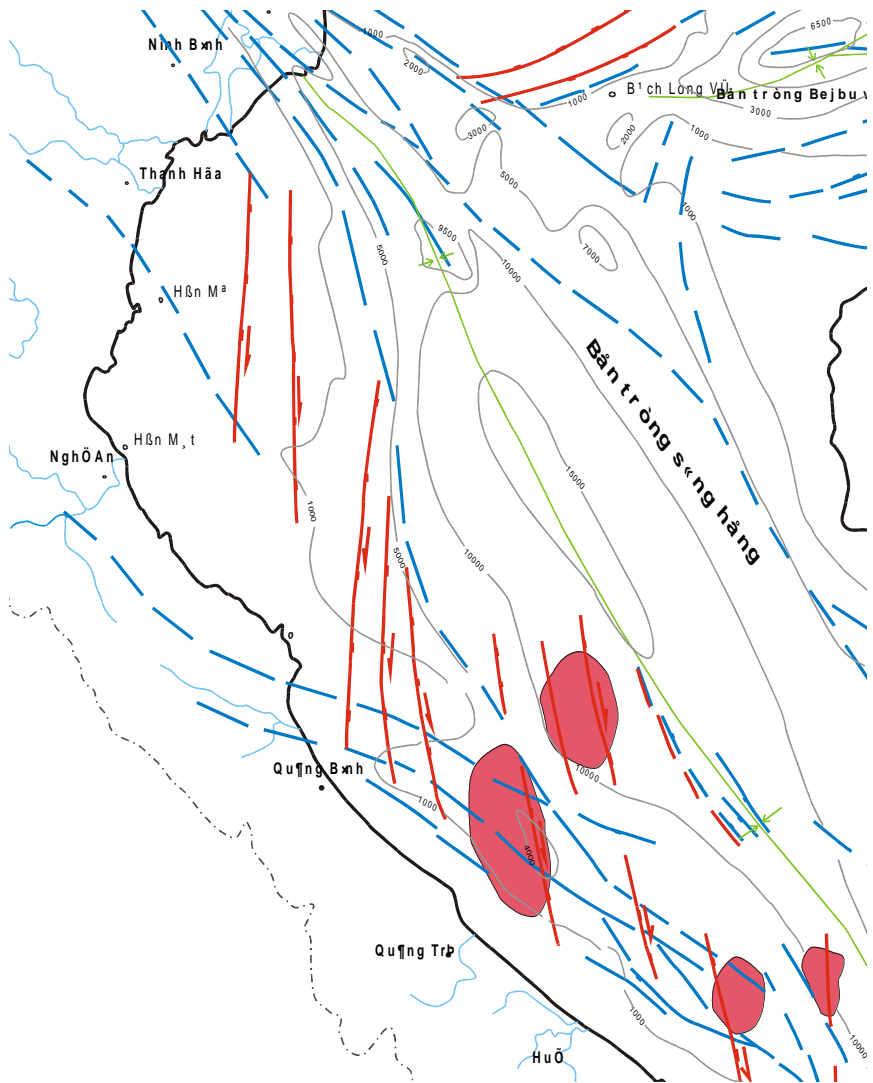
- Scheme of tsunamigenic zones in Southeast Asia
- Catalog of tsunamis in Southeast Asia
- Tsunami source zones in South China Sea region
- Zones of volcanoes in the South China Sea
- Zone of potential of landslides



Scheme of tsunamigenic faults in Southeast Asia

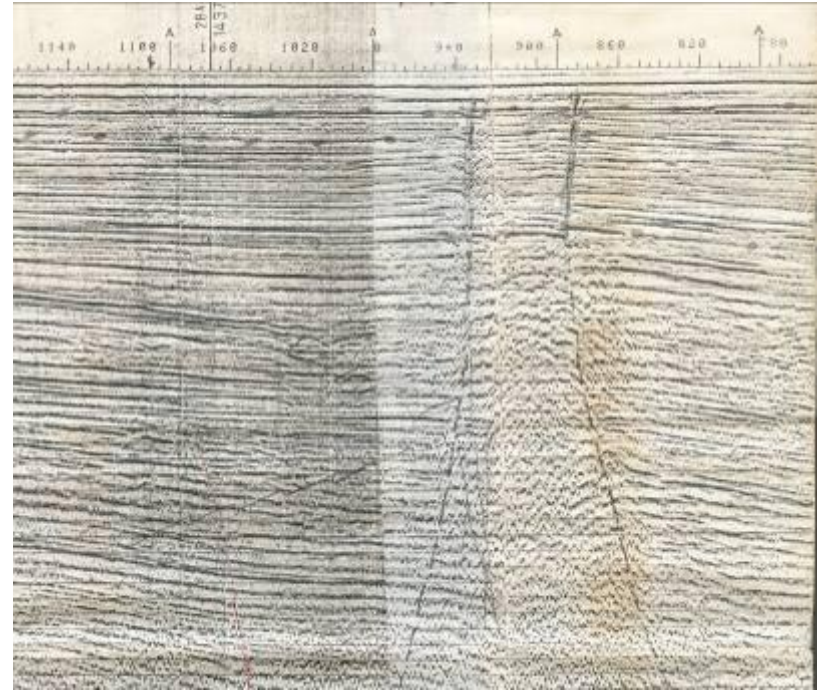
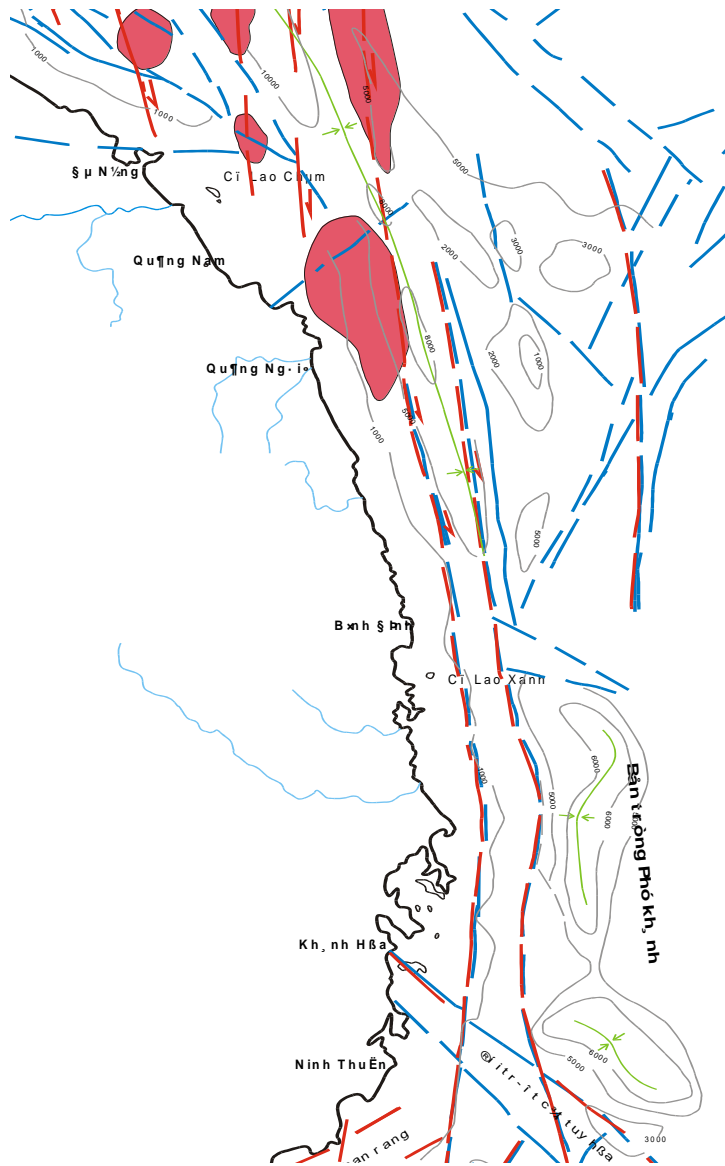


Tsunami source zones in South China Sea region



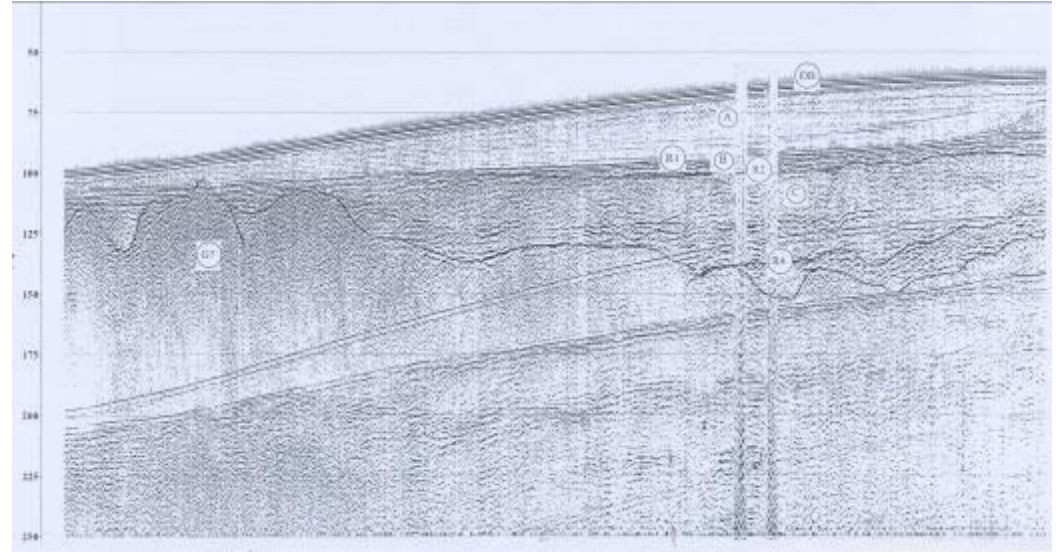
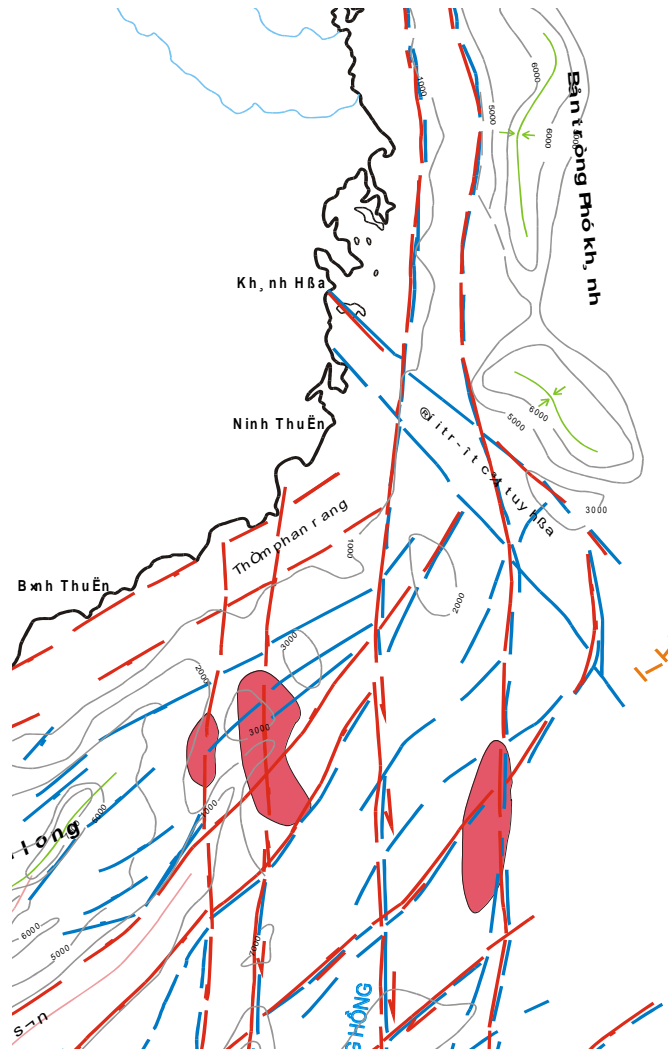
The seismic section

Neotectonic activities along coastal zone
in the north part of Vietnam



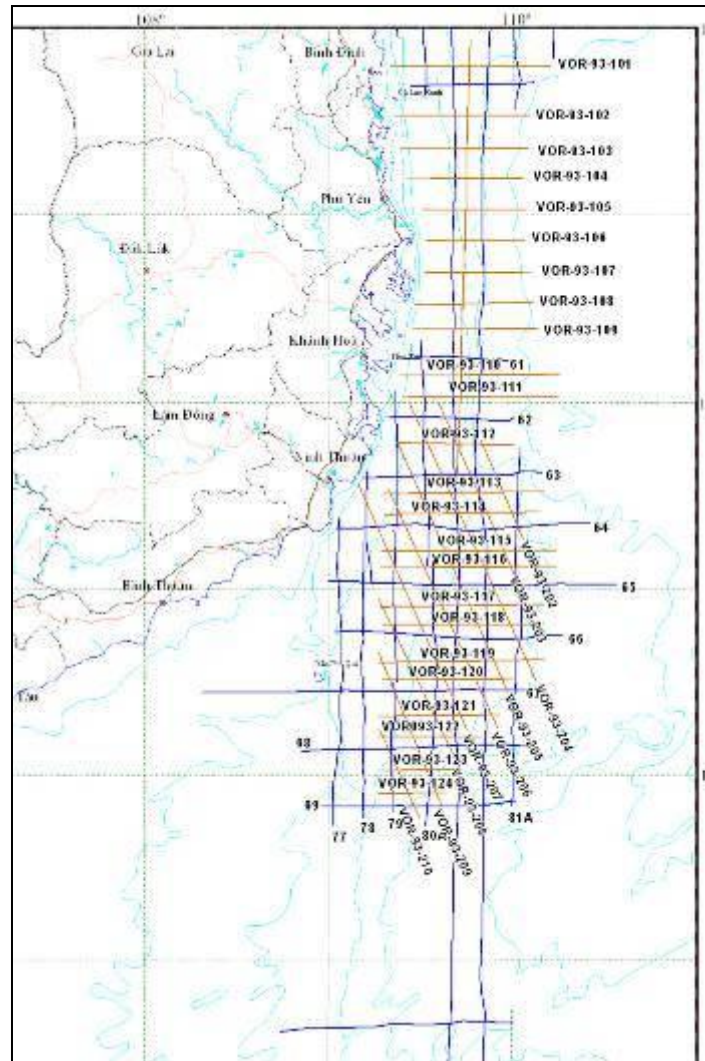
The seismic section

Neotectonic activities along coastal zone in the central part of Vietnam

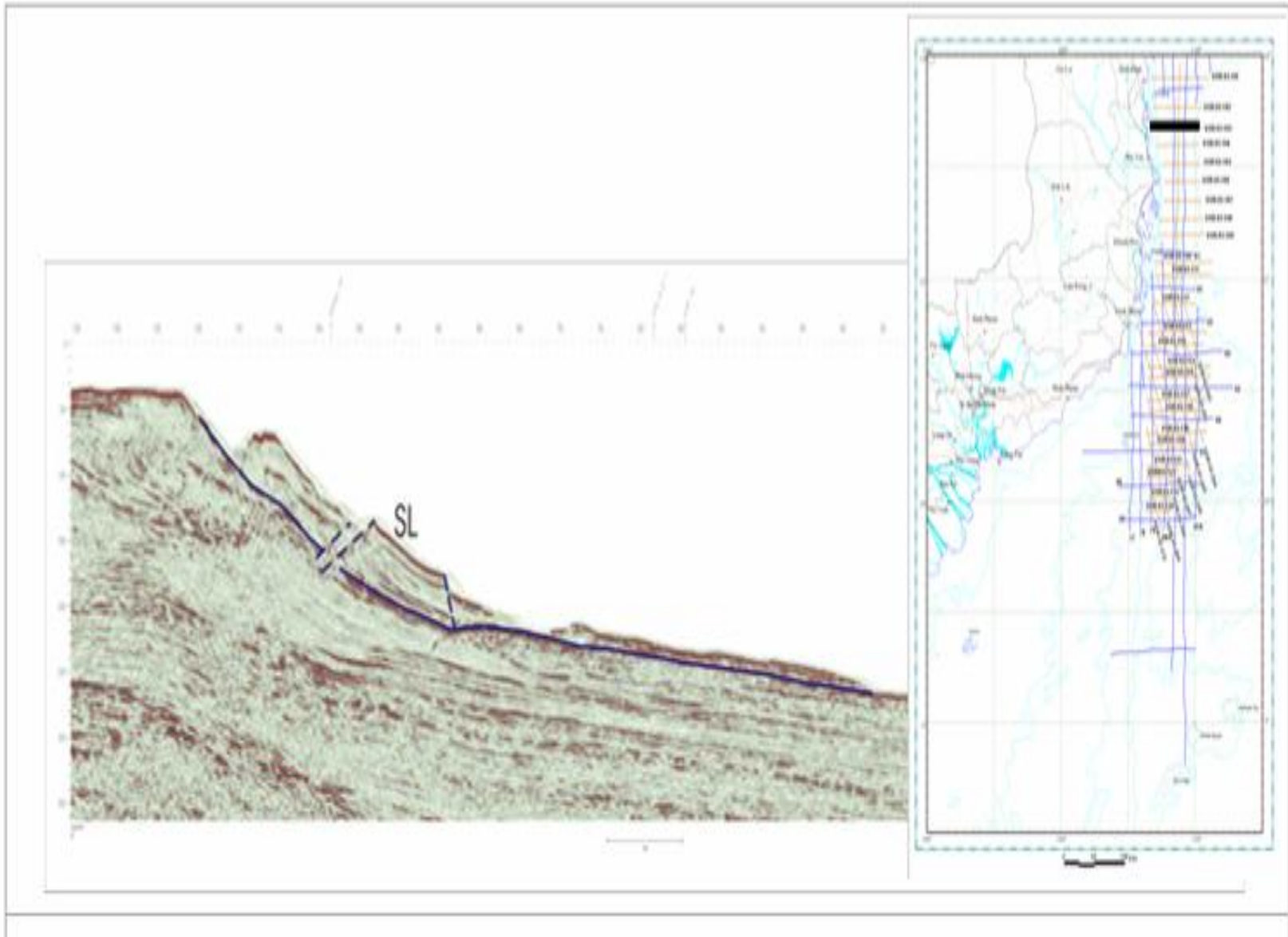


The seismic section

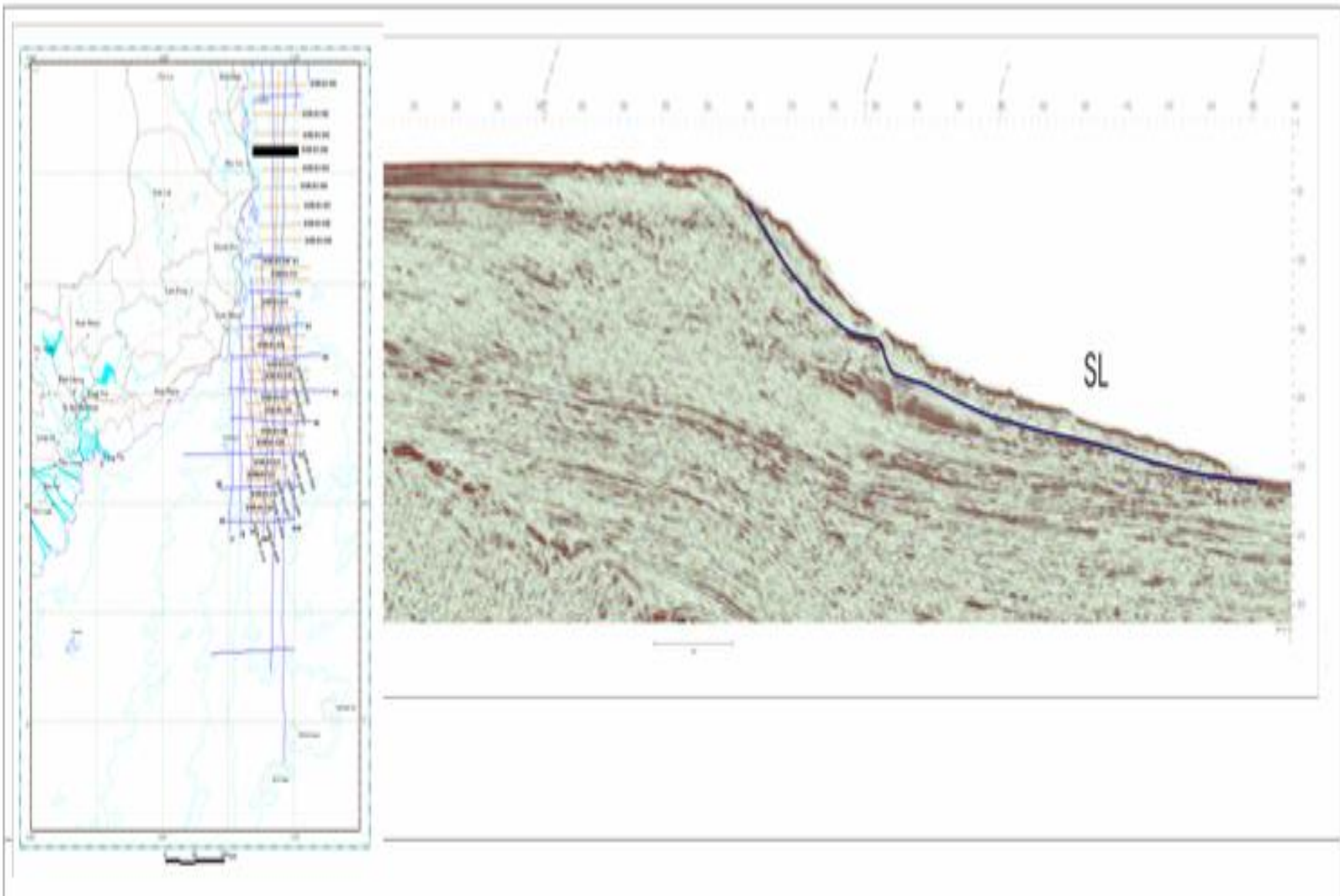
Neotectonic activities along coastal zone in the south part of Vietnam



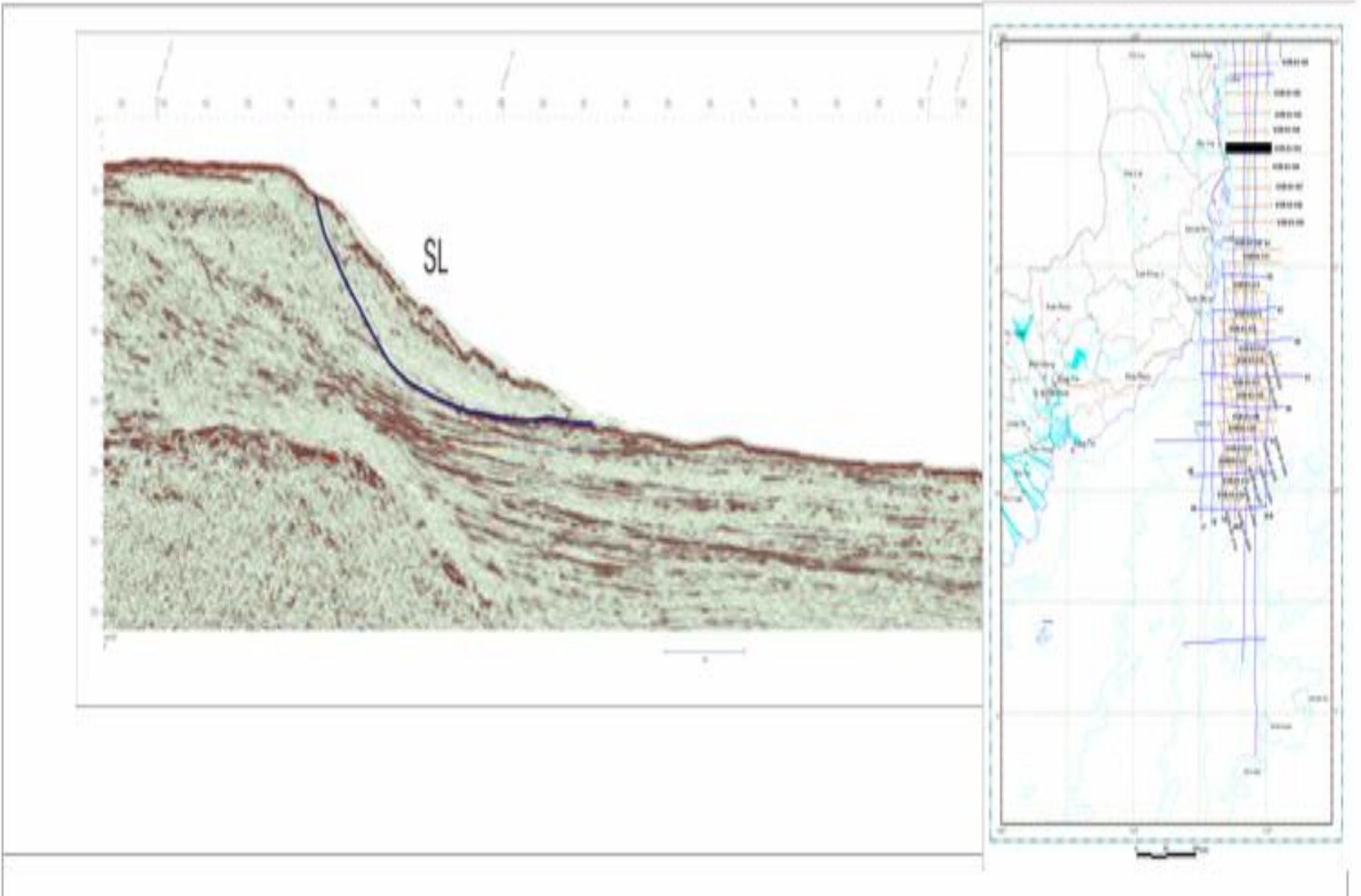
Seismic profiles to study landslide potential in coastal area of central and southern Vietnam



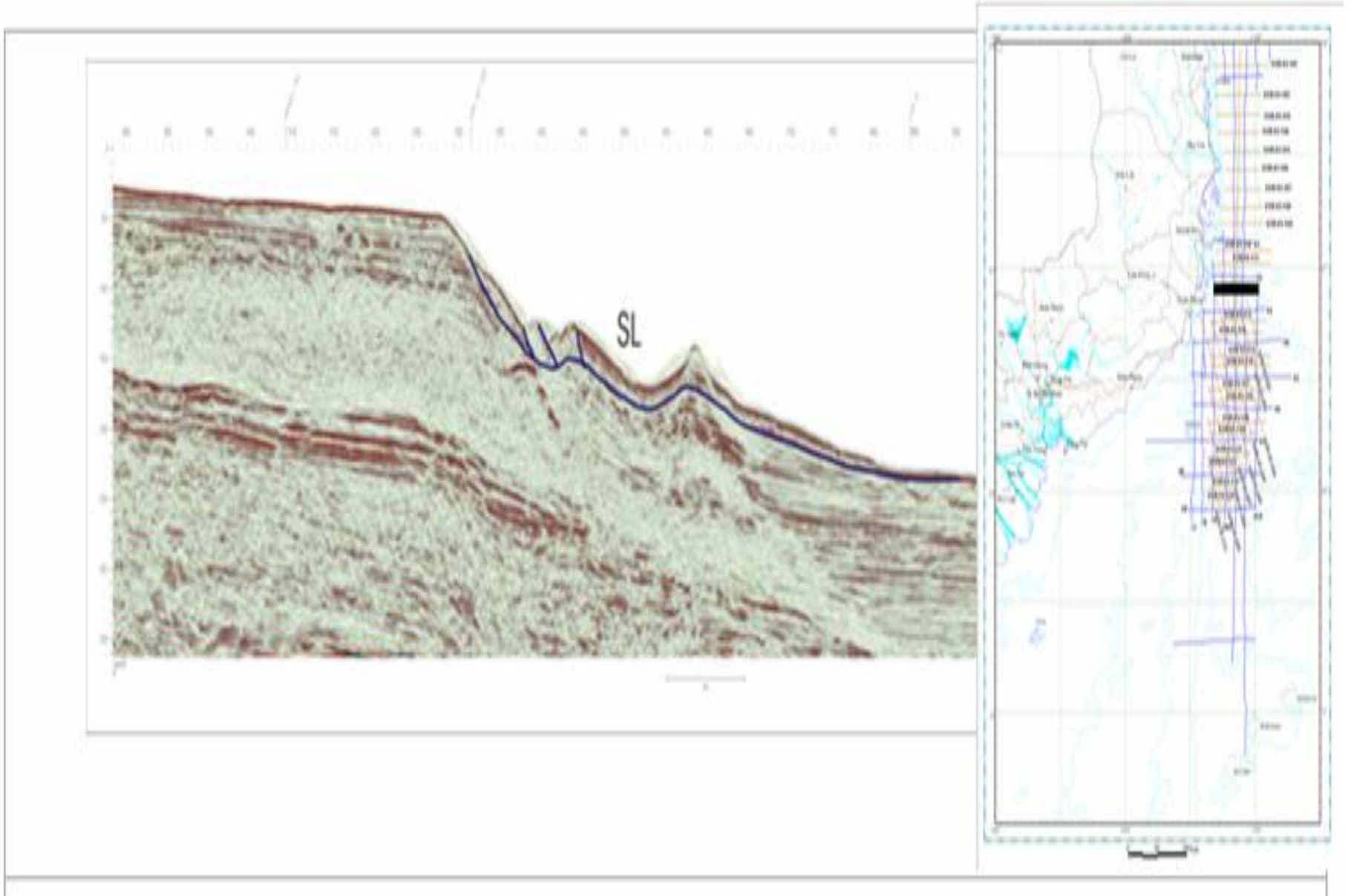
Seismic profiles VOR 93-103



Seismic profiles VOR 93-104



Seismic profiles VOR 93-105



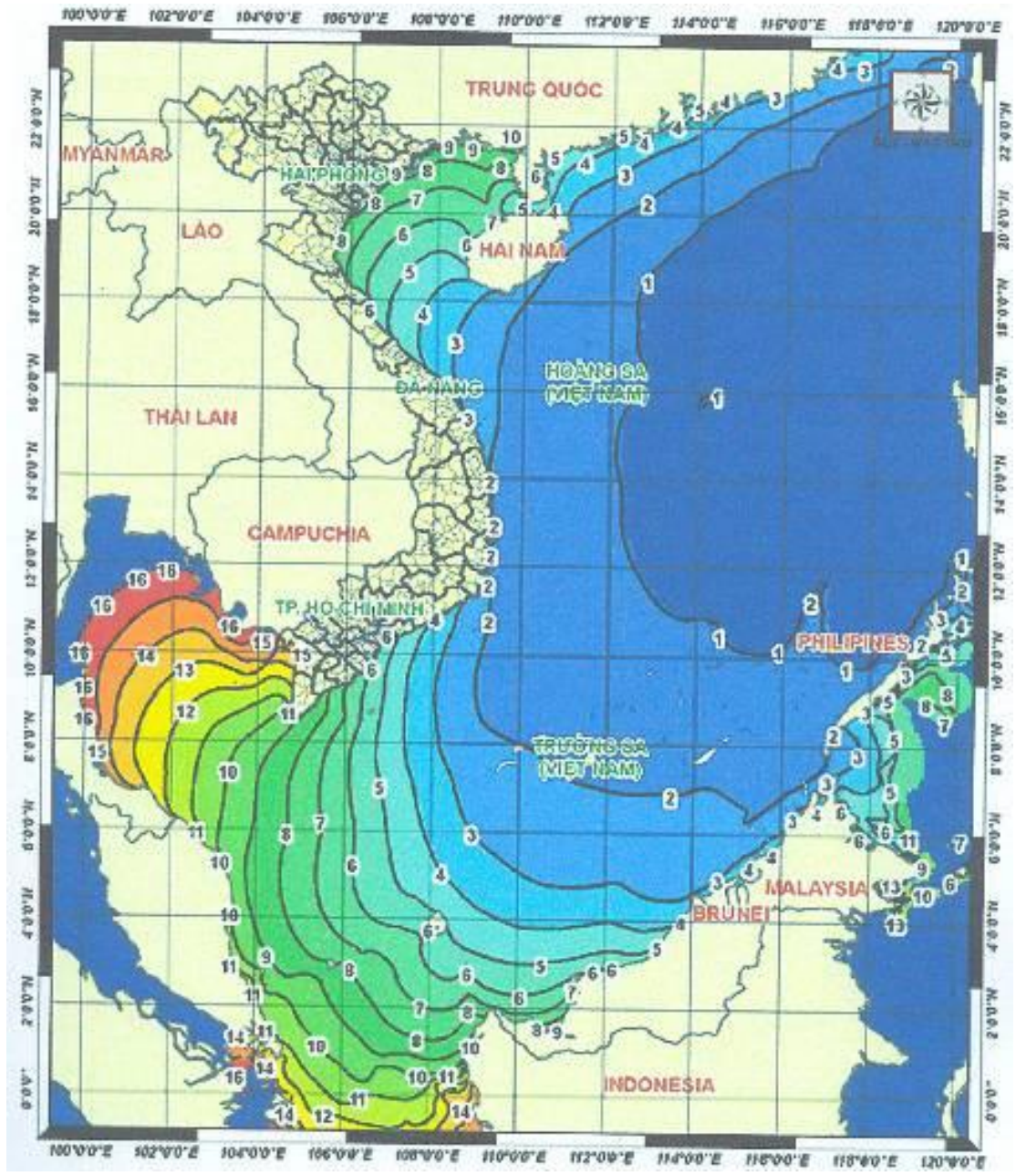
Seismic profiles VOR 93-112

TSUNAMI AFFECT EVALUATION

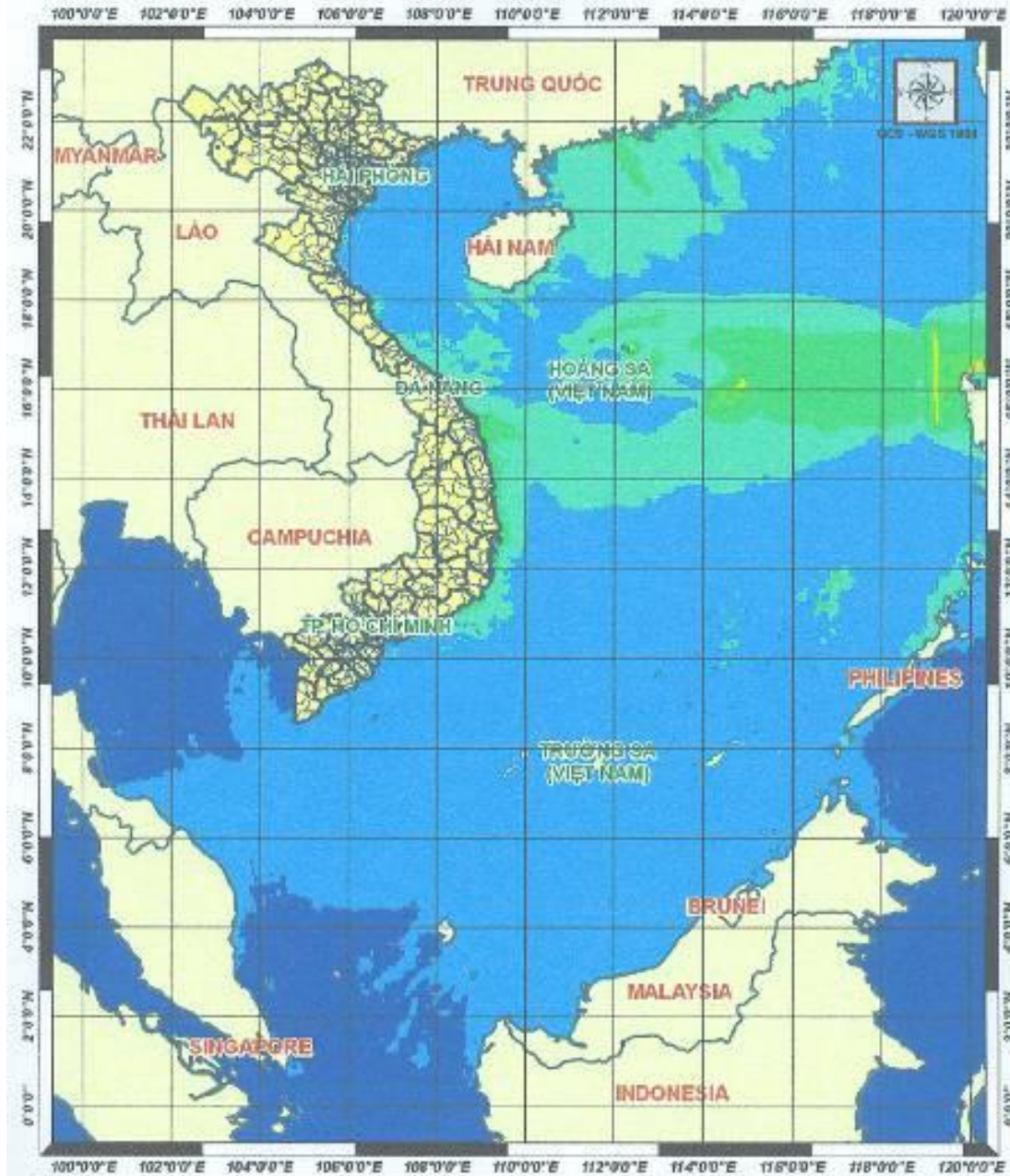
- Evaluation of Mw for Tsunami source zones
- Calculation model for Tsunami propagation and inundation
- Identification of appropriate Tsunami scenarios
- Simulation of Tsunami propagation and Inundation for coastal areas of Vietnam

SOURCE PARAMETERS OF MAIN TSUNAMI SCENARIOS

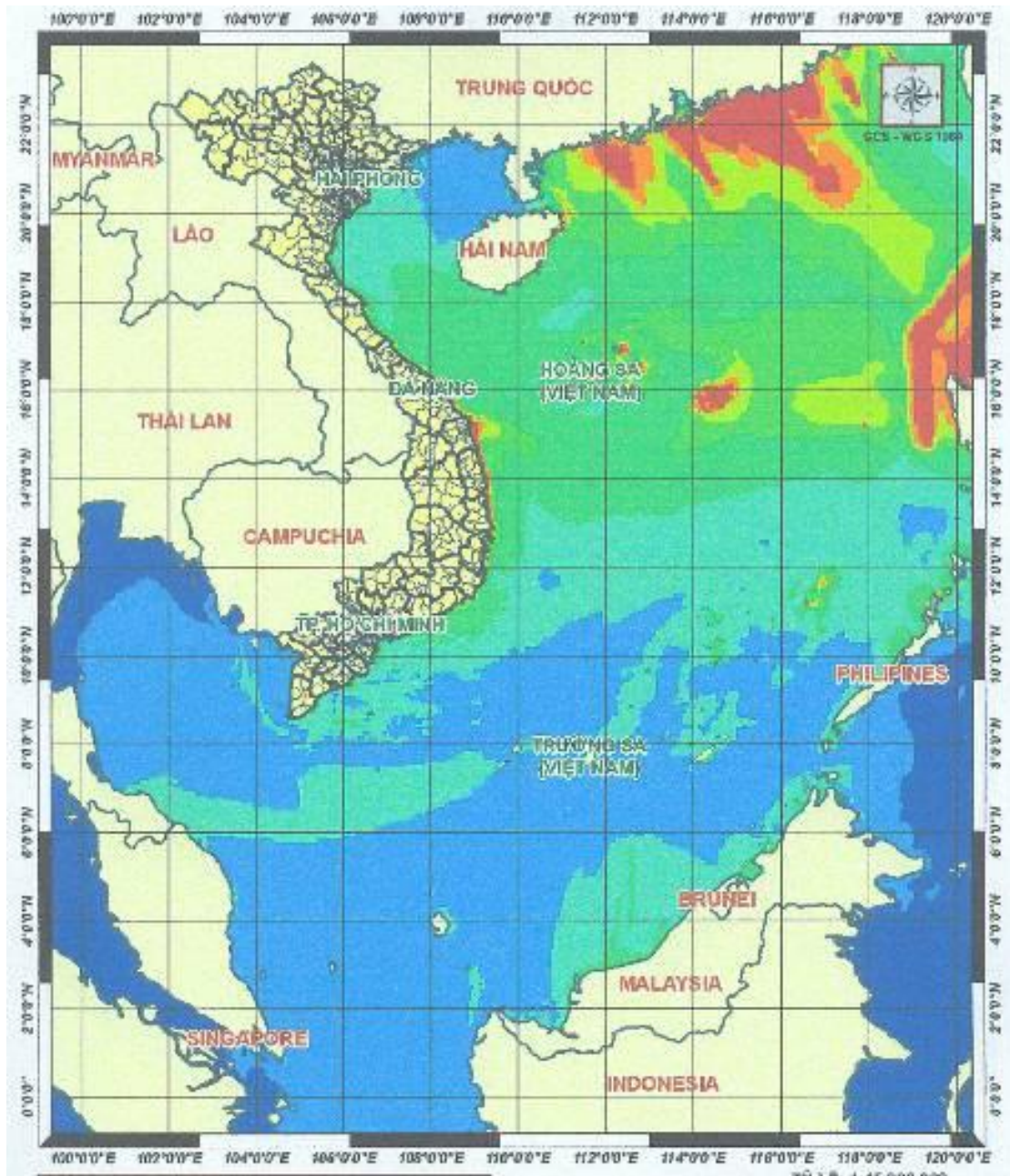
Source zone	M_w	L (km)	W(km)	Dislocation (m)	Strike	Dip.	Slip	H (km)
Manila Trench (Eastern source zone)	8.0	160	45	5	357	40	90	20
	8.5	280	80	9	357	40	90	30
	9.0	500	140	15	357	40	90	30
Western source zone	6.5	30	8	1	180	90	-90	6
	7.0	50	15	1.7	180	90	-90	10
North source zone	7.0	50	15	1.7	57	78	90	10
	7.5	90	25	3.0	57	78	90	17



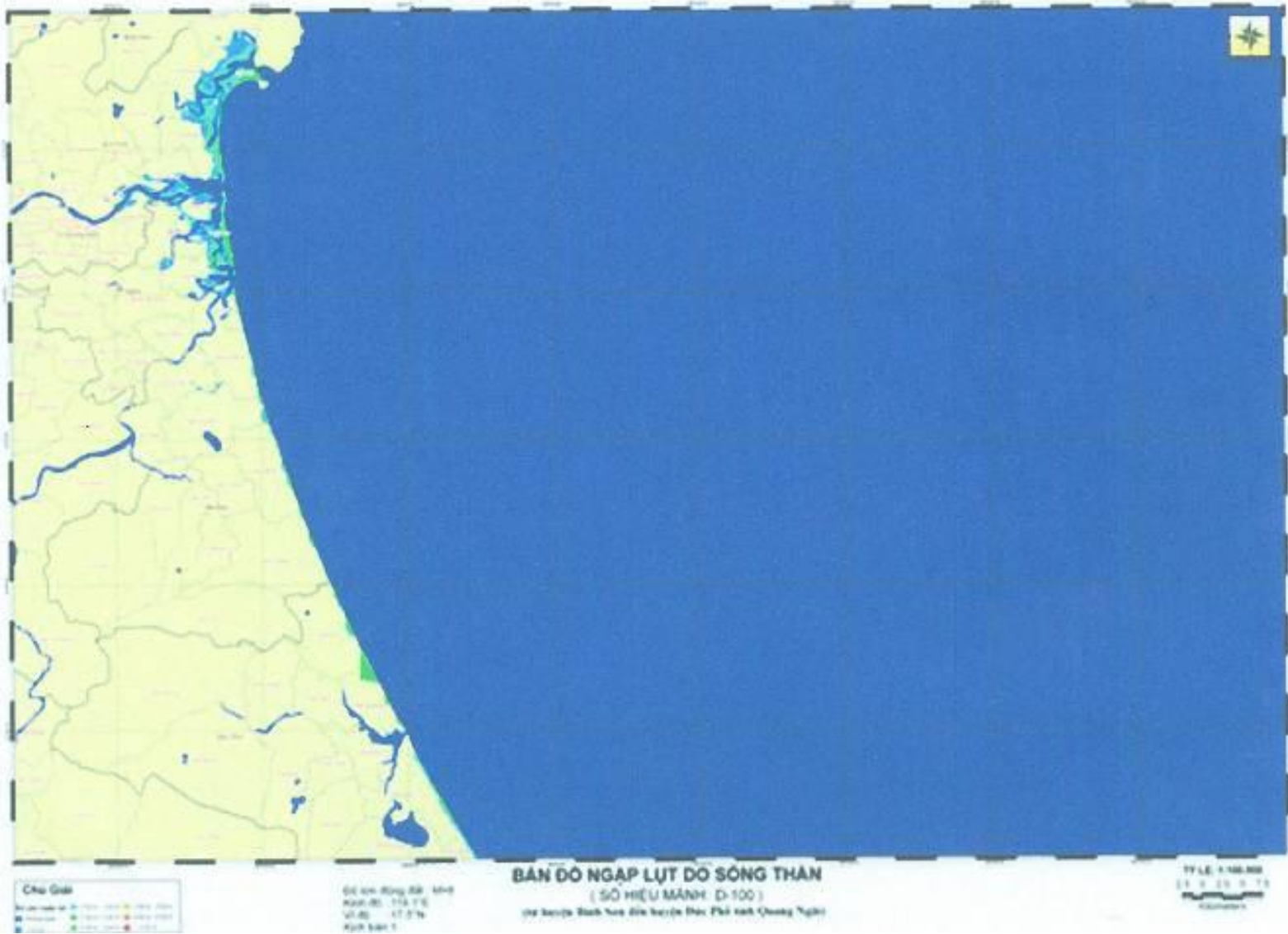
Scenario 1: Tsunami propagation time from Manila Trench. $M_w=9.0$



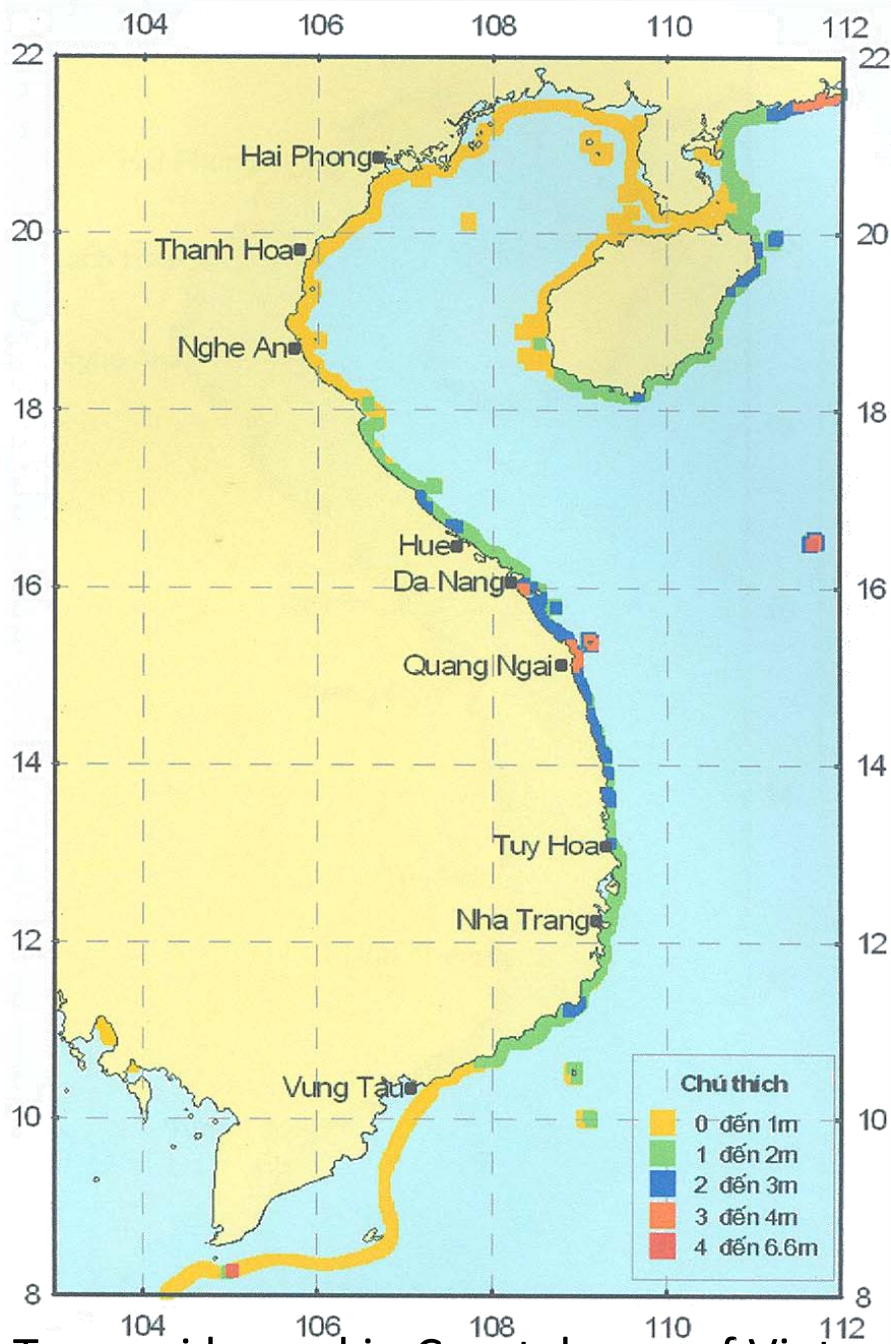
Scenario 2: Tsunami propagation from Manila Trench. $M_w=8.5$



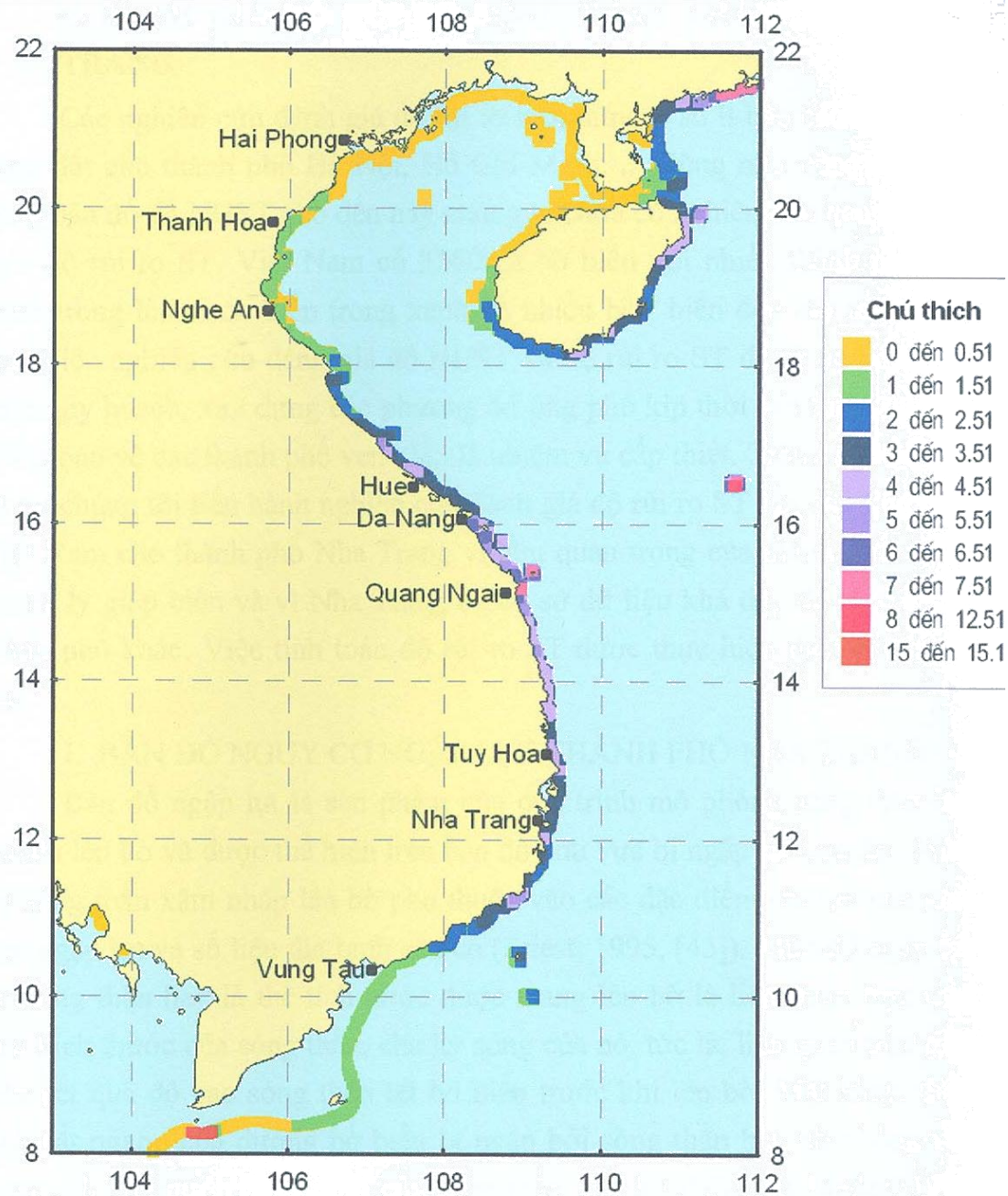
Scenario 3: Tsunami propagation from Manila Trench. $M_w=9.0$



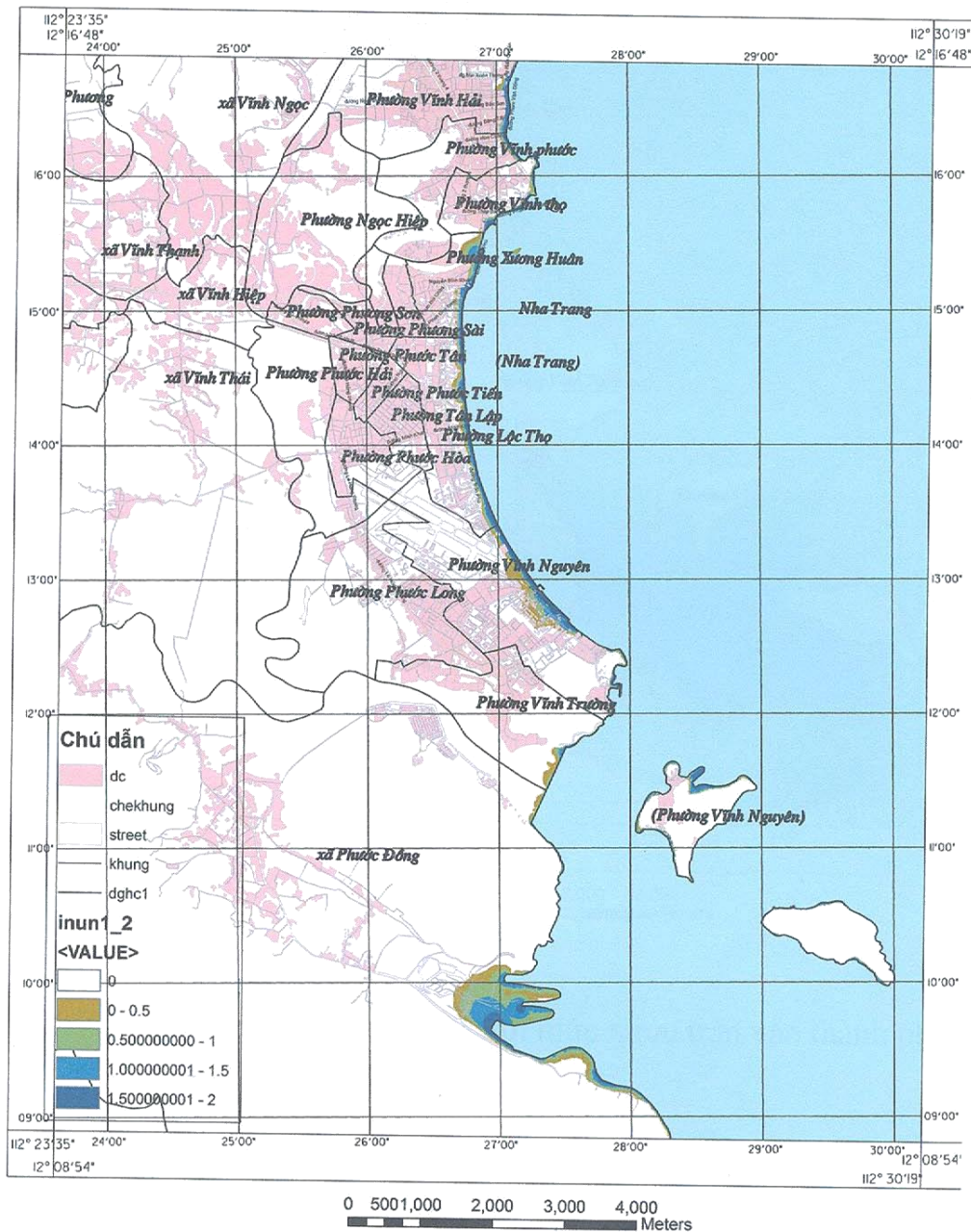
Scenario 4: Tsunami inundation. Tsunami from Manila Trench. $M_w=8.0$



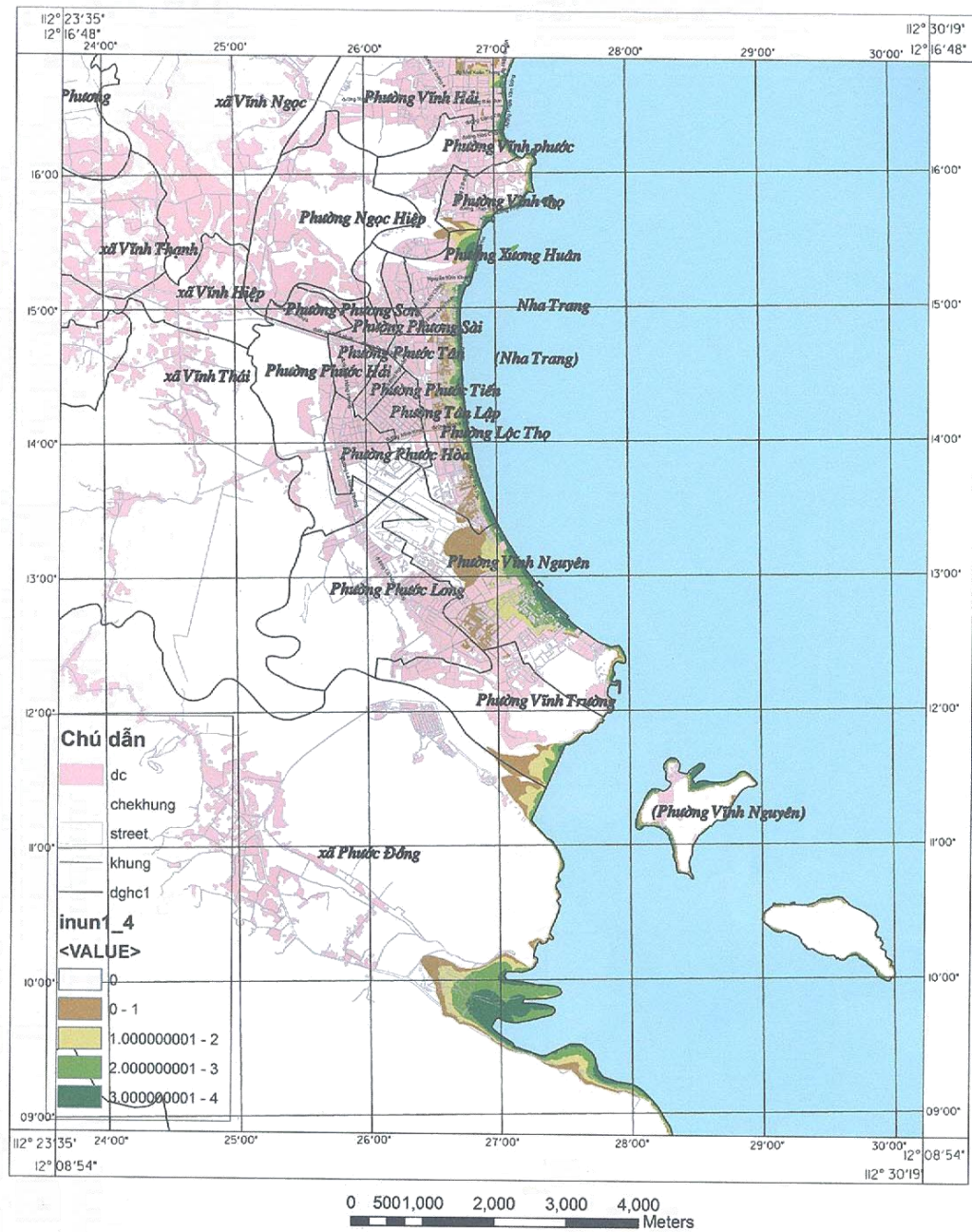
Tsunami hazard in Coastal area of Vietnam for return period of 950 years



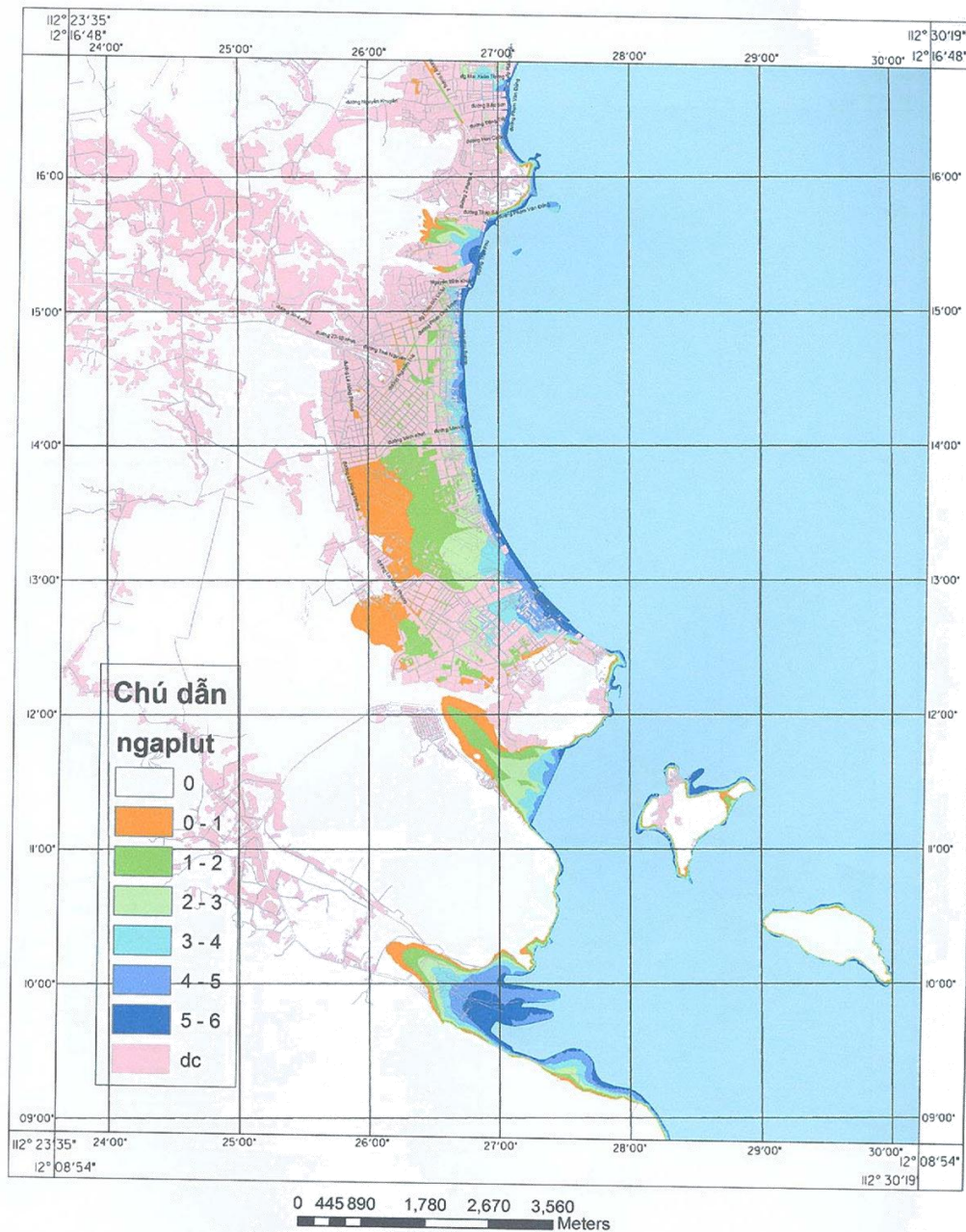
Tsunami hazard in Coastal area of Vietnam for return period of 2500 years.



Inundation in Nha Trang city with
Tsunami wave height = 2m



Inundation in Nha Trang city with
Tsunami wave height = 4m



Inundation in Nha Trang city with
Tsunami wave height = 6m

MEASURES FOR HAZARD MITIGATION

- Detail seismic sounding and geological investigation for meridional fault system along central and south central coastline
- Conduct of earthquake and Tsunami risk assessment for central and south central coastal zone of Vietnam
- Establishment of National system for earthquake information and Tsunami warning
- Development of mangrove forest areas and protecting forests along coastal zone
- Education and training of earthquake and Tsunami hazard preparedness for the population and community
- Conduct of drill for earthquake and Tsunami preparedness and rescue

VIETNAM NATIONAL SYSTEM FOR EARTHQUAKE INFORMATION AND TSUNAMI WARNING

1. Legislation bases
2. Earthquake Information and Tsunami Warning Centre
3. Institute of Geophysics (IGP)
4. Vietnam National Seismic Network (Vietnet 2010)
5. Operation System for Earthquake Information and Tsunami Warning

LEGISLATION BASES

1. Prime Minister decision No 264/2006/QD-TTg, November 16, 2006 on "Regulation of earthquake information and Tsunami Warning in Vietnam"
 - Information for all earthquakes with $M > 3,5$
 - Alert with tsunami warning for coastal areas and islands.
 - Institute of Geophysics is an only agency responsible for earthquake information and tsunami warning in Vietnam
 - Improvement of national seismic network and tidal station system to serve earthquake information and tsunami warning
 - Establishment of earthquake information and tsunami warning centre
 - Responsibilities of Government offices and localities authorities to support earthquake information and tsunami warning system

LEGISLATION BASES

2. Prime Minister decision No 78/2007/QD-TTg, May 29, 2007 on "Regulation and Guideline for earthquake and Tsunami preparedness and prevention"
3. Decision No 1798/QD-KHCNVN, September 4, 2007 on establishment of the earthquake information and tsunami warning centre belong to Institute of Geophysics
4. Decision No 1798/QD-KHCNVN, December 21, 2007 on approval to project for improvement of National Network of Seismic Stations in Vietnam. Realization in period of 2008-2012

THE EARTHQUAKE INFORMATION AND TSUNAMI WARNING CENTER

- Location: Institute of Geophysics, Hanoi
- Functions:
 - To receive and process data and information of the seismic networks, sea level stations and buoys
 - To provide information of the earthquakes and tsunami warning to TV, radio, the Government offices and localities
 - To provide guideline for earthquake and tsunami preparedness and prevention
- Working staff: 12 people

INSTITUTE OF GEOPHYSICS

Building A8, 18 Hoang Quoc Viet - Cau Giay - Hanoi
Tel: 84. 4. 7567305
Fax: 84. 4. 8364696

**Institute founded in 1986 by Vietnamese Government decision
No.60/HDBT/15-05-1986**

RESEARCH AND DEVELOPMENT FUNCTIONS

- Investigation of geophysical fields (gravity, geomagnetic, geoelectric and geothermal)
- Investigation of seismicity and seismic zoning
- Study of the earth crustal structure and geodynamics,
- Study of atmosphere physics
- Development and application of geophysical methods of prospecting
- Earthquake information and tsunami warning in the territory of Vietnam and adjacent sea areas
- Postgraduate training in geophysics

ORGANIZATIONAL STRUCTURE

- Research departments
 - Seismology
 - Seismic observation (seismological network)
 - Geomagnetism
 - Geodynamics
 - Geophysical methods of prospecting
 - Atmosphere physics
 - Ionosphere observatory
- Administrative and management office
- Operation center for earth information and tsunami warning
- Current member of researchers: 80
(Ph.D:15, M.Sc: 20)

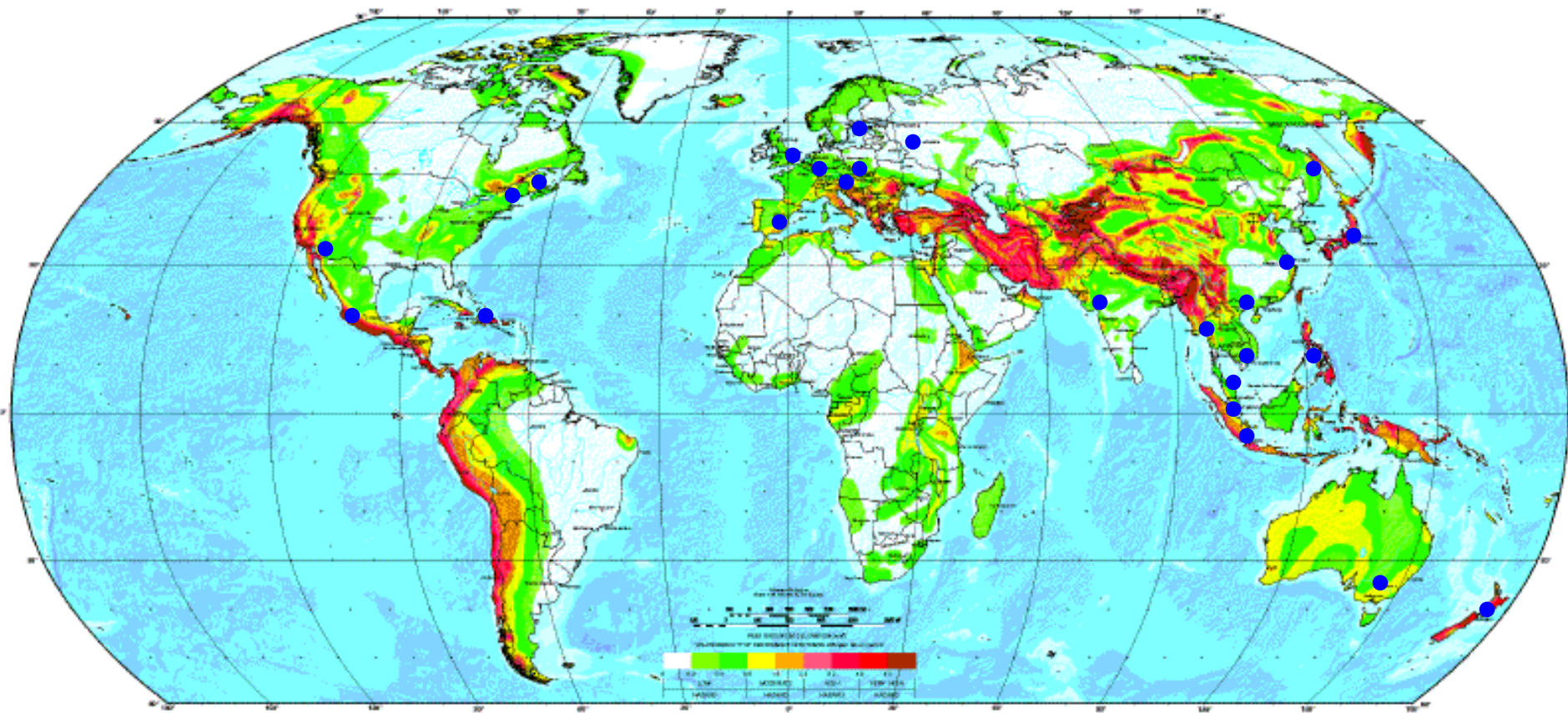
MAIN COMPLETED NATIONAL RESEARCH PROJECTS

- Seismicity and seismic zoning in Vietnam territory (1990)
- Seismicity and seismogenetic zones in Eastern sea of Vietnam (2000)
- Seismicity and detail seismic zoning in northeastern part of Vietnam (2005)
- Scientific and technological bases for protection of underground water resources in Vietnam (2007)
- Compilation of atlas of natural conditions and environment in sea areas of Vietnam (2005)
- Study of structure and dynamics of faults in area of Hoa Binh hydroelectric plant
- Earthquake and tsunami hazards and risk assessment in the coastal areas of Vietnam (2007-2008)

MAIN SCIENTIFIC EQUIPMENTS AND FACILITIES

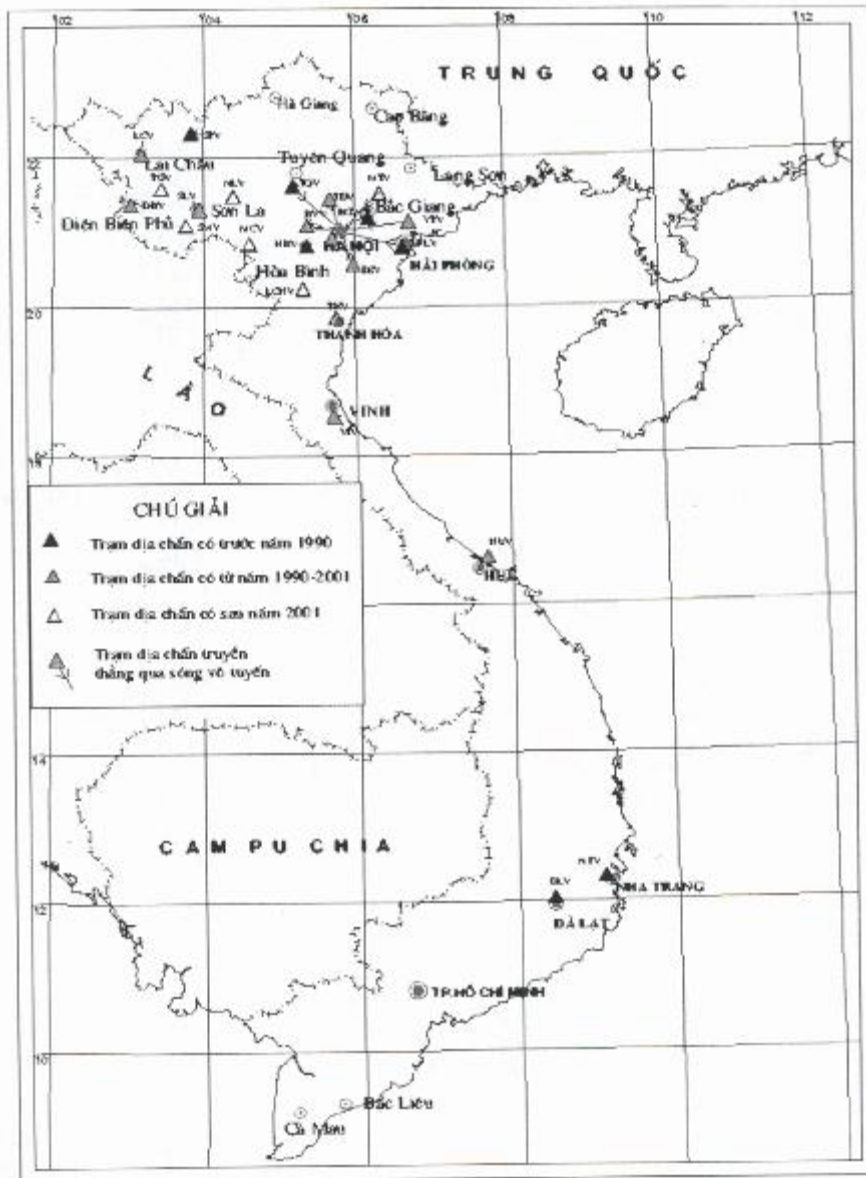
- Network of 25 seismological stations in Vietnam territory
- 4 geomagnetic observatories (Sapa, Dalat, Bac Lieu, Hanoi)
- 9 atmospheric physics stations
- System of 9 teleseismic station
- Operation center for earthquake information and tsunami warning
- 15 digital seismometers
- 24 channels seismic sounding unit
- Geophysical equipments (gravity meters, magnetometers, geoelectric sounders)
- Ionosphere sounders

INTERNATIONAL COOPERATION OF IGP

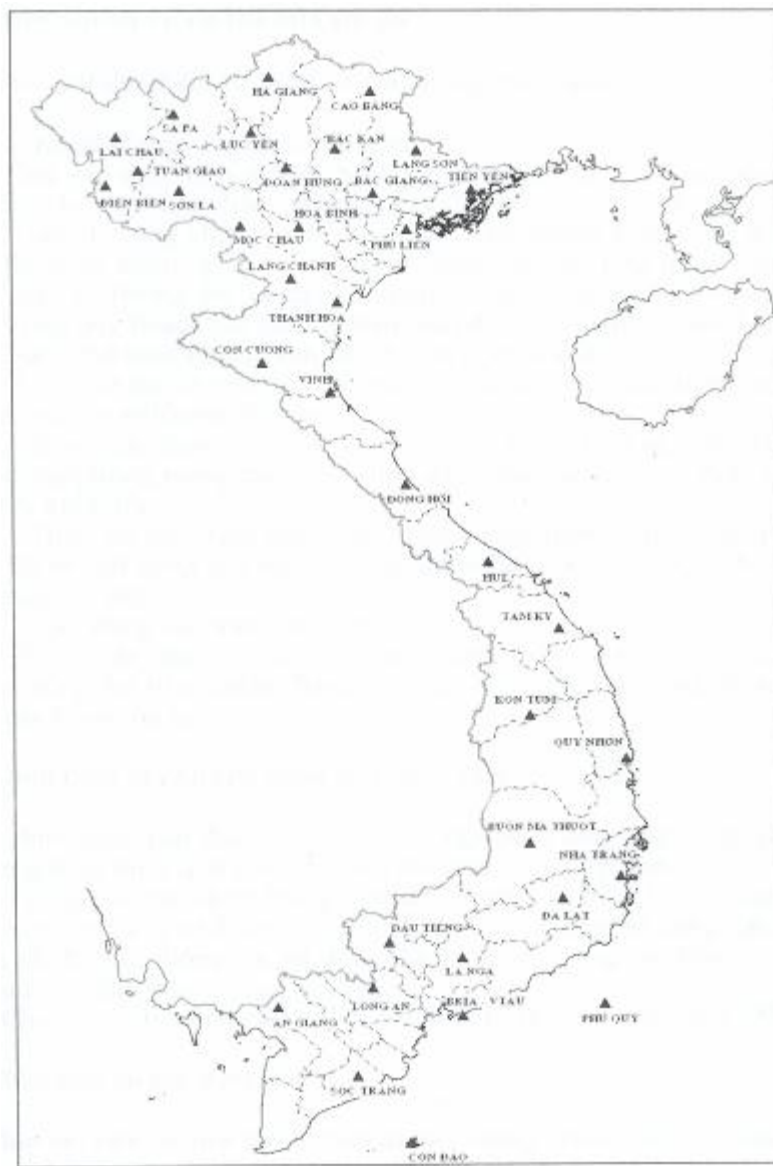


VIETNAM NATIONAL SEISMIC NETWORK (VIETNET)

- Present status: 25 stations
 - North Vietnam: 20
 - Central Vietnam: 3
 - South Vietnam: 2
 - Seismographs: L-4C-1D (8) and L-4C-3D (17)
T=1
- Project for Vietnet 2008-2012: 36 stations
 - North Vietnam: 18
 - Central Vietnam: 8
 - South Vietnam: 10
 - Seismographs: Broadband remote seismic stations GPS systems
 - Satellite system for data transmission
 - Data acquisition and processing centre (in Hanoi)

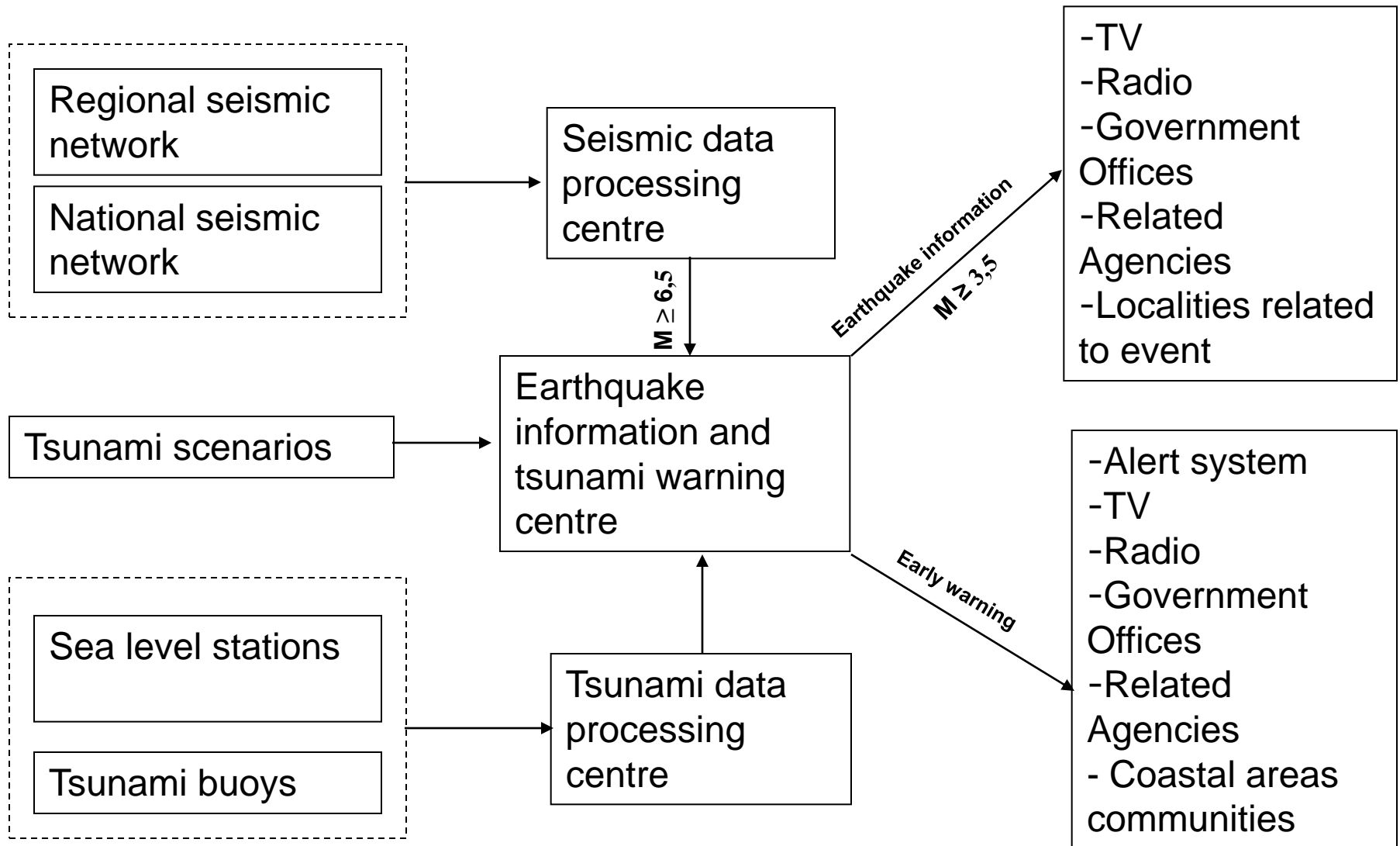


Seismic Network of Vietnam



Seismic Network of Vietnam for 2010-2012

OPERATION SYSTEM FOR EARTHQUAKE INFORMATION AND TSUNAMI WARNING IN VIETNAM



CONCLUSIONS

1. Coastal areas of Vietnam are a zones of complicated geological structure and active seismotectonics as places of meeting and crossing by most seismoactive fault systems of NW-SE direction in land and NE-SW, N-S directions faults along coastline in the sea.
2. Depending from geological structure and seismicity coastal area of Vietnam characterized by strong and differenced Earthquake hazard with PGA changes from 0,18 gal to 0,08 gal with return period of 950 years and ground A. Highest Earthquake hazard characterized for the north and north central areas, while lowest Earthquake hazard are make in the south and south central areas.

CONCLUSIONS

3. Coastal areas of Vietnam may be affected by Tsunami from source zones as Manila Trench subduction zone and seismogenic fault systems along northeast and west coastline of the South China Sea. Tsunami may have a maximum height of 6-8m with return period of 950 years in central and south central coastal areas.
4. Main measures for seismic risk mitigation in coastal areas of Vietnam are:
 - Improvement and modernization of national seismic stations network
 - Promotion of national system of Earthquake information and Tsunami warning in close cooperation with another national systems and international networks in the region.
 - Enhancement of research and investigation in the field of seismotectonics and detail seismic hazard and risk assessment.

The end!

THANKS FOR YOUR ATTENTION!