Refinement of the Source Parameters of the 1948 M8.1 Panay Island Earthquake

By

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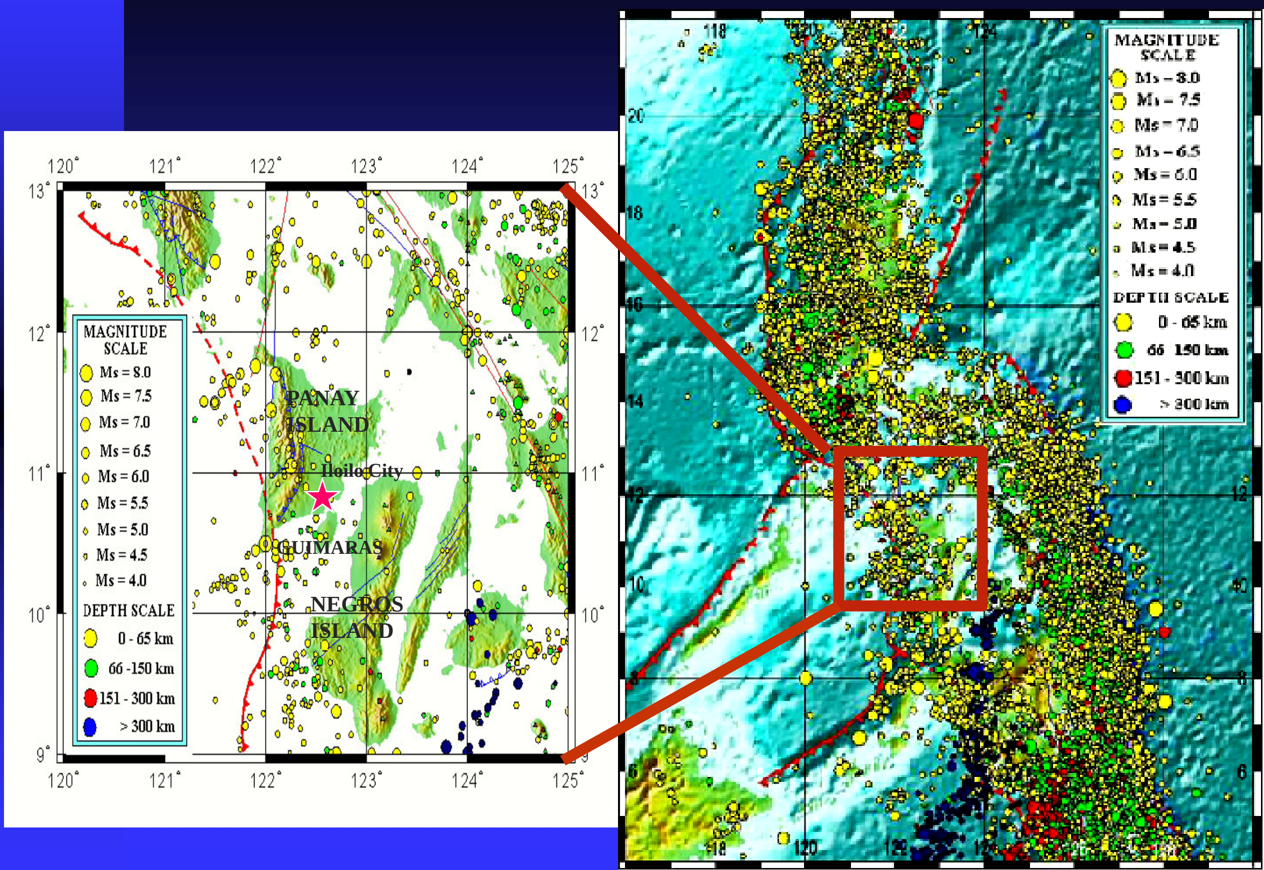
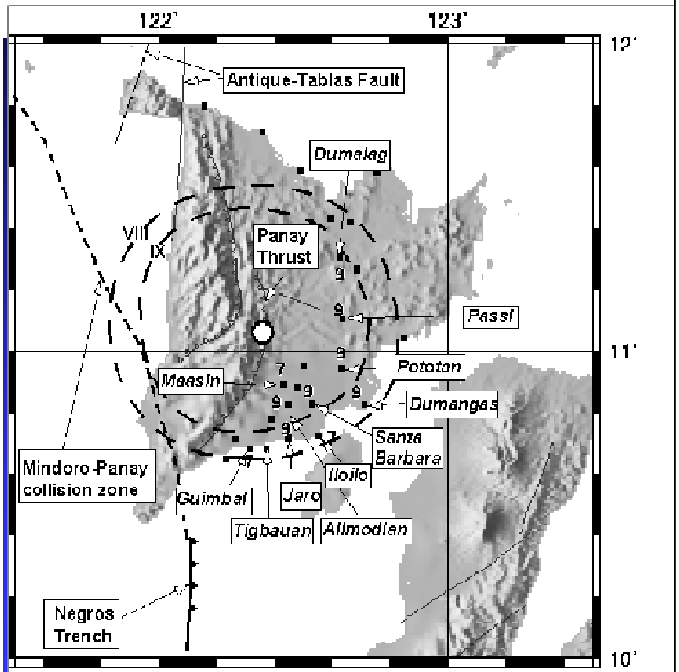
Seismicity around west Visayas from 16th century to present



The Earthquake of 1787 (Mag 7.4)

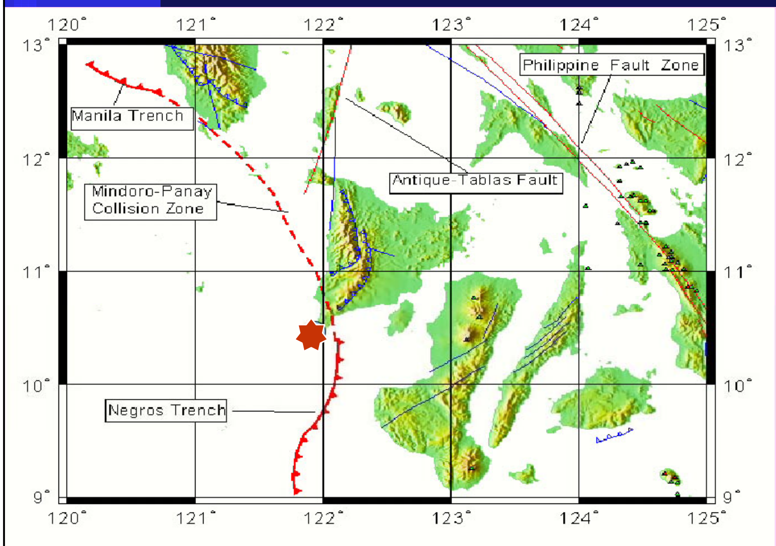
- The stone churches of Pototan, Santa Barbara, Jaro, Dumangas, Passi, Laglag (Duenas) and Alimodian (Iloilo Province) totally collapsed
- Dumalag (Capiz) and Maasin (Iloilo) – churches were partially destroyed
- The churches of Miagao and Guimbal survived

References: Letter of Fr. Juan Campos, ----; Abella y Casariego, 1890; Maso, 1895, 1927; Milne, 1912;Repetti, 1946; MLPBautista, 1999



Isoseismal map of the 1787 July 13 earthquake (6:45 AM). Filled circle signifies estimated epicenter; filled squares are locations of known and established towns during this time. Italicized names are places mentioned in earthquake accounts. This is being related to the movement of the East Panay Thrust. Roman numbers are intensities in MMI. A(IX) is 5810 sq. km (Ms 7.5) and A(VIII) is 9010 sq. km (Ms 7.3). Ms(ave) is 7.4.

1948 Panay Earthquake



- The earthquake is characterized by intense ground shaking, extensive liquefaction and landslides and a report of small tsunami
- Date: January 25, 1948
- Time: 12:45 AM
- Magnitude: 8.1 (Second biggest in the Philippines
- Depth: fixed to 33
- Location may not be accurate due to very few local seismic stations

Prior to this study, the only known data about this earthquake were the following:

- 55 churches in Panay Island were damaged, 17 of which totally collapsed and 20 cracked beyond repair
- Iloilo City – 5-storey Jaro belfry collapsed
- Arevalo – Coronet tower was ruined
- Antique – 50% of the houses were ruined
- Waves along Iloilo Strait were observed. Two persons died

References: Bulletin of the Seismol. Soc. Am., 1948; Murphy and Ulrich, 1951a; Iida et al, 1967;Berninghausen, 1969, SEASEE, 1985

Why is this earthquake interesting?

- The 1948 M8.2 Panay Island Earthquake is one of the biggest but least studied earthquake in the Philippines.
- There are no scientific studies made and written accounts are also very meager since it happened barely two years after World War II when the Philippines was still trying to recover from the ravages of the war.
- The location of the epicenter which is at the southern tip of Panay island is doubted since the simulated intensities do not match the actual damage distribution.
- There were accounts of tsunamis which need to be verified.
- It is important to ascertain the source fault for future seismic hazards and risk assessment Purposes.
- The people who witnessed the earthquake are now 75 years old and above and are now disappearing one by one.

Methodology

- Accurately determine the actual intensity distribution
- Compare this with simulated intensity distribution computed using the adjusted fault plane location and orientation.
- The fault plane parameters that give intensity distribution that closely match the actual intensity distribution is considered as the more acceptable source parameters of the event

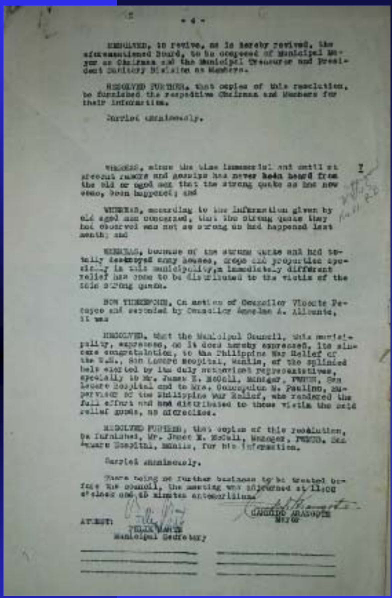
Methodology for Generating Historical Intensity Distribution Map

- Gathered written accounts of earthquake impacts from old newspapers which are archived in the National Library and from historical reports from historians of local government units
- Conducted actual interviews of residents who are 75 years old and above (12 years old and above in 1948)
- Onsite observations of existing damaged structures such as old churches which are the only remaining masonry structures at that time

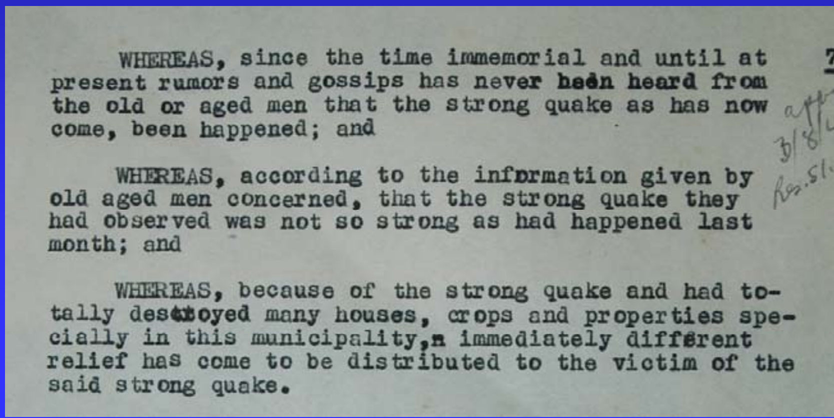
Data Sources: Library, Museum and Church Materials,local historians, eyewitnesses, earthquake catalogs, internet, etc

Data Sources: Newspaper accounts

Official Documents that tell of the effects of the earthquake: Bugasong, Antique



Town Historian



WHEREAS, since the time immemorial and until at present rumors and gossips has never heen heard from the old or aged men that the strong quake as has now come, been happened; and

WHEREAS, according to the infprmation given by old aged men concerned, that the strong quake they had observed was not so strong as had happened last month; and

WHEREAS, because of the strong quake and had totally destroyed many houses, crops and properties specially in this municipality, immediately diffèrent relief has come to be distributed to the victim of the said strong quake.

Minutes of Meeting,
February 16, 1948
Municipality of Bugasong

Intensity Survey thru Eyewitness Accounts

We searched for eyewitnesses 75 yrs old and above (Antique, Iloilo and Guimaras)

Interview Proper

Part I: Personal information and setting the time recollection of events

Part II: Earthquake and Tsunami recollections



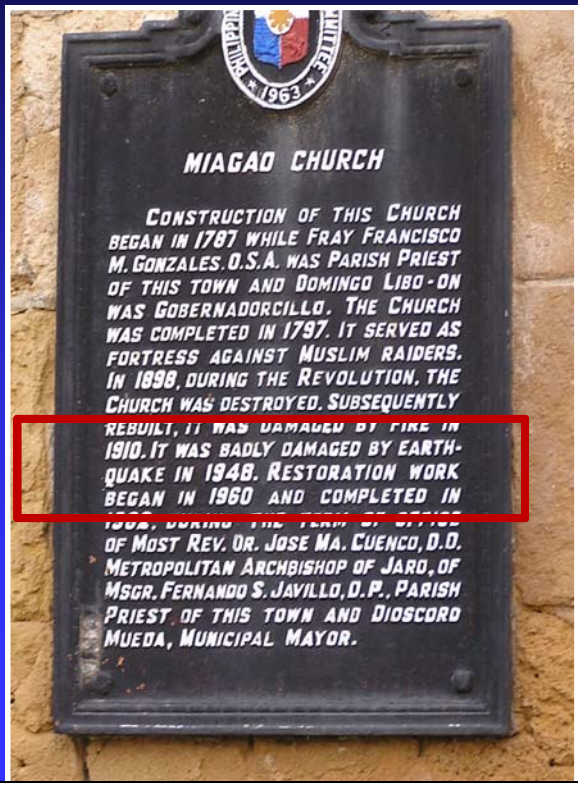








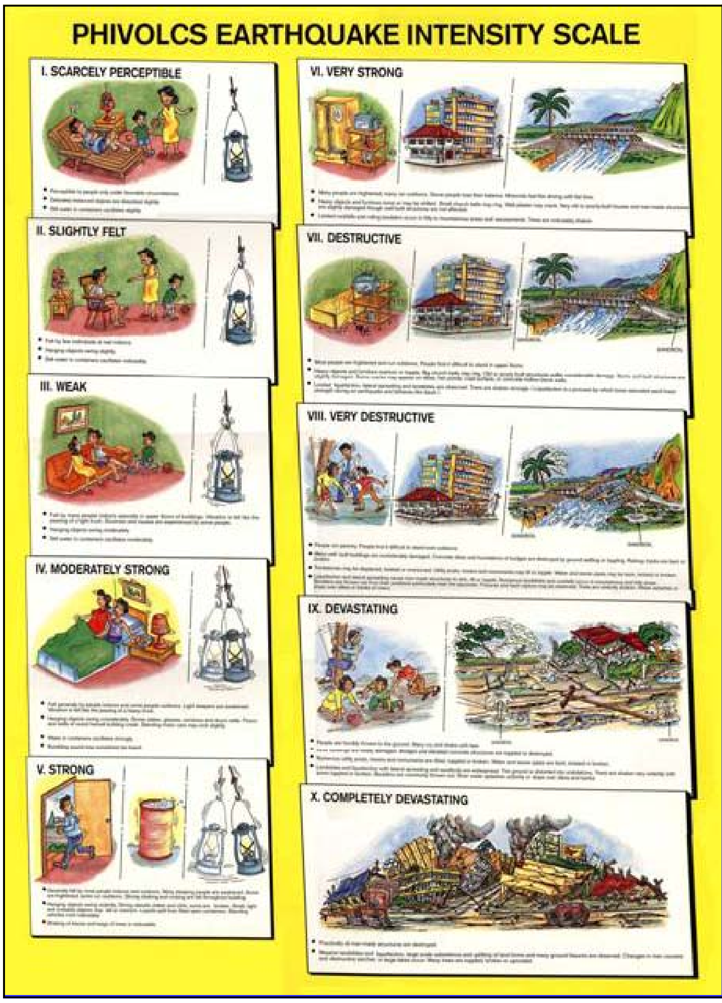

Evaluation of Intensity Based on Damage to Churches



Description of Construction Type

- Pre 1787 Construction Materials

- Pre 1948 Construction Materials



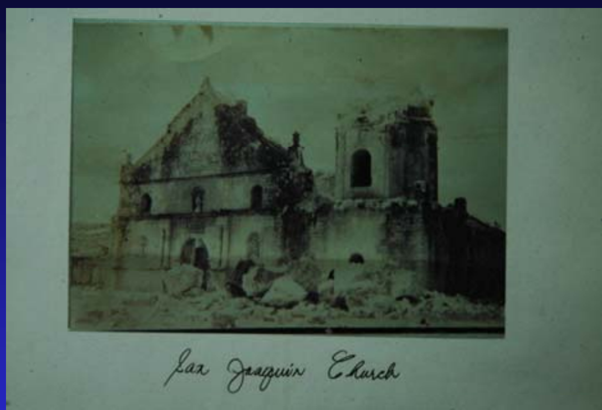
PHIVOLCS Earthquake Intensity Scale (PEIS)

Criteria for Evaluating Intensities Based on Damage to Old Churches

Facade	Cracks (wall)	Partial Damage(Wall)	Total Damage (Wall)	Roof collapse	Belltower Collapse	Intensity (PEIS)
√			√	√	√	Int IX
√		√		√	√	Int VIII
√		√			√	Int VIII
√	√				√	Int VIII
	√				√	Int VIII
	√			√		Int VII
	√					Int VI

In the epicentral area in Anini-y, Antique

Near the epicentral area in San Joaquin, Iloilo

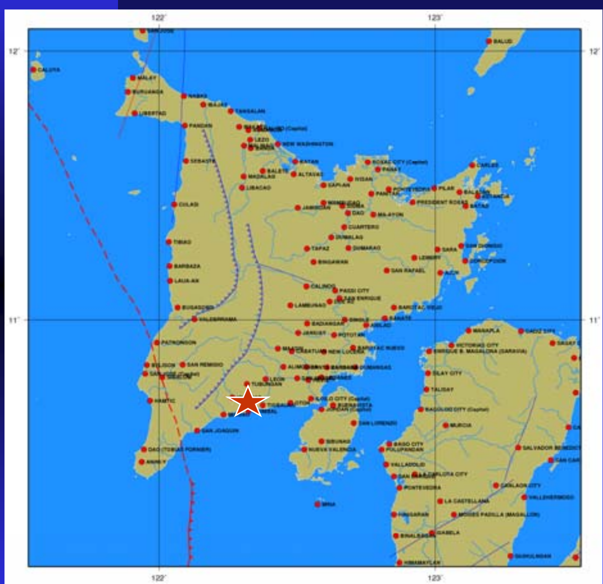


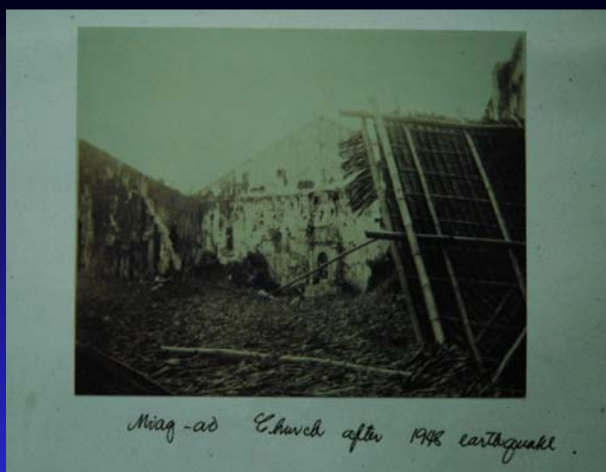
Photos of earthquake damage courtesy of Jaro Archbishop Archives Office

Effects in Duenas, Iloilo

Photo of earthquake damage courtesy of Duenas Church

Effects in Miagao, Iloilo

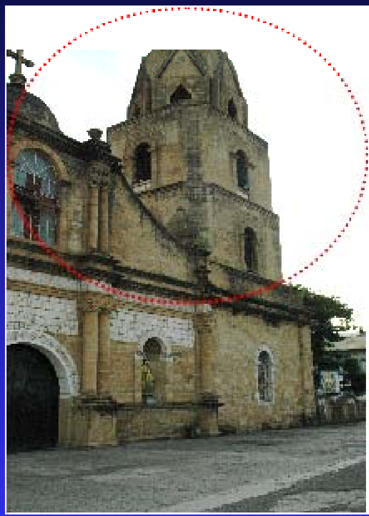




Present-day Miagao Church: UNESCO heritage site

(Photo of damaged Courtesy of Jaro Archdiocese Archives)

Effects to Guimbal Church in Guimbal, Iloilo



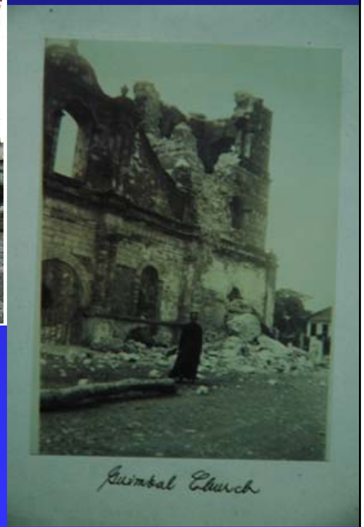
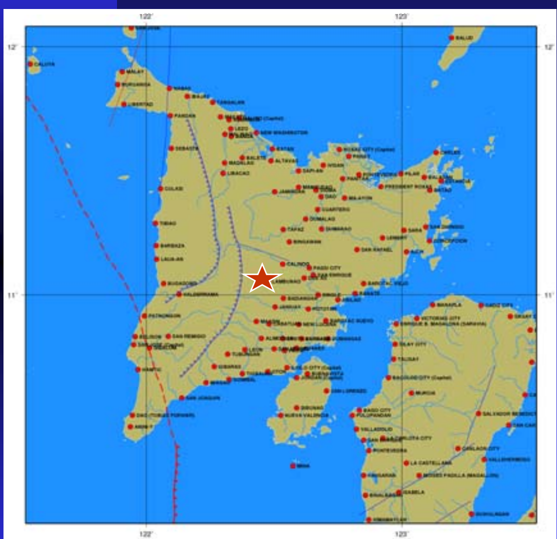


Photo Courtesy of Jaro Archdiocese Archives

Effects to Lambunao, Iloilo



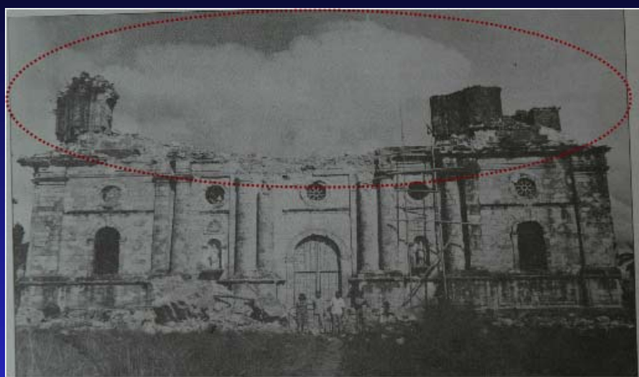
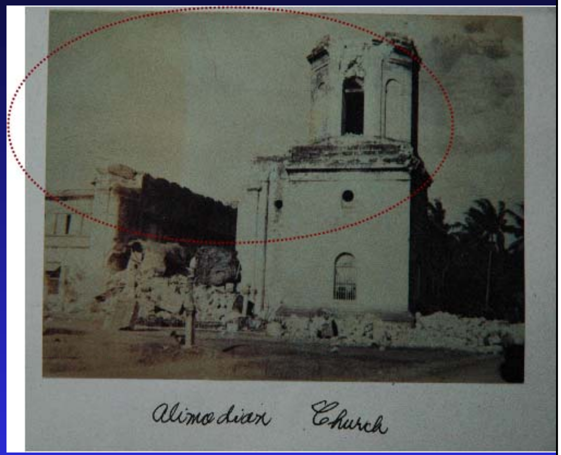


Photo of damage Courtesy of Lambunao Fiesta Program

Effects to Alimodian, Iloilo



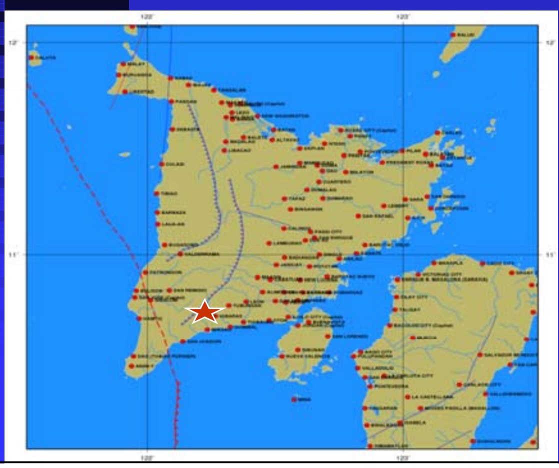
Present-day Alimodian Church

Upper Photos Courtesy of Alimodian Historical Society (upper left) and Jaro Archdiocese Archives

Effects to Igbaras, Iloilo

Pre-1948 Igbaras Church totally collapsed

Pre-1948 Igbaras Church

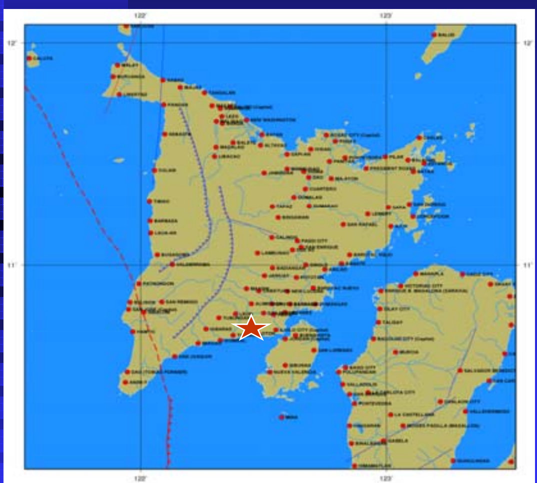


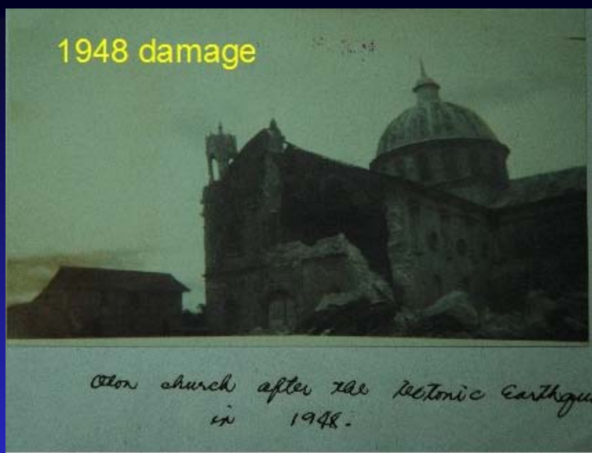
Present- day Igbaras Church

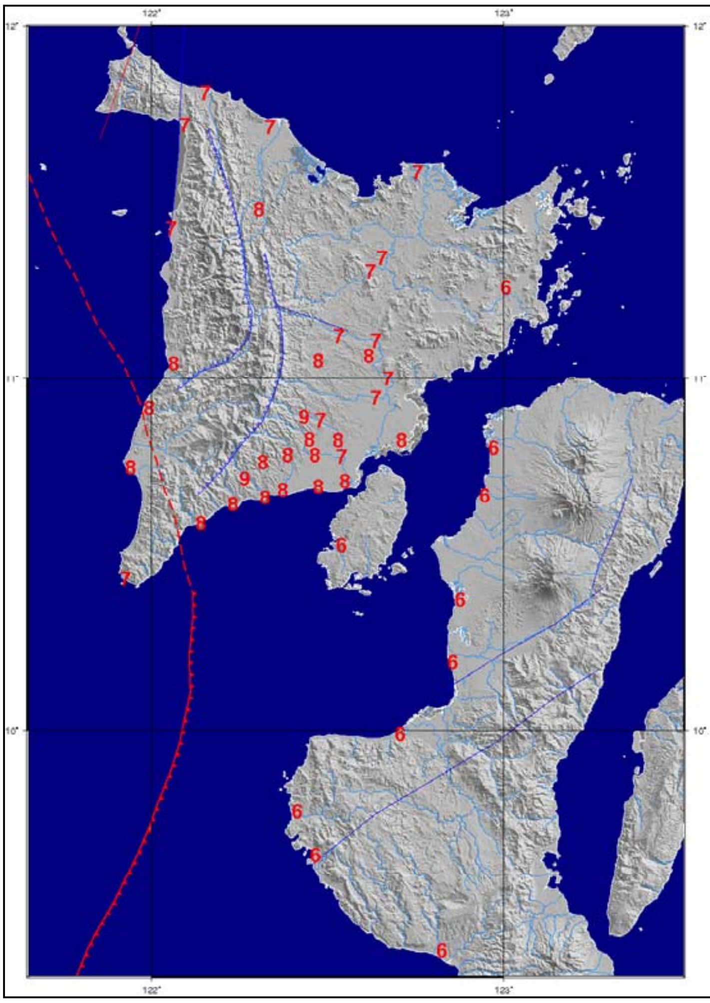
Photo of damage Courtesy of Jaro Archdiocese Archives)

Coronet Tower, Arevalo District, Iloilo City

Effects in Oton, Iloilo







Observed Intensity Distribution Map

Factors that determine the severity of ground shaking

- Location
  - Proximity to seismic source
- Local soil condition
  - Effect of local soils to ground shaking
  - Amplification/de-amplification

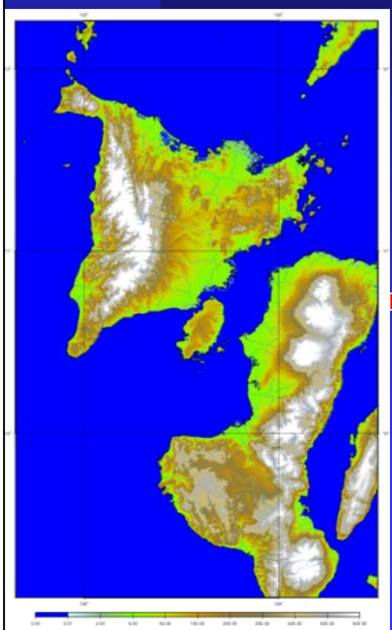
Intensity Simulation Using Empirical Method

- We used the Fukushima and Tanaka ground attenuation model (1990) to compute for PGA at rock site
- Fault rupture was calculated from the Fault length-Magnitude relation of Wells and Coppersmith (1994)
- Vs30 Site amplification model determined from SRTM slope map
- This amplification model was verified using H/V microtremor observation and REMI microtremor measurements.

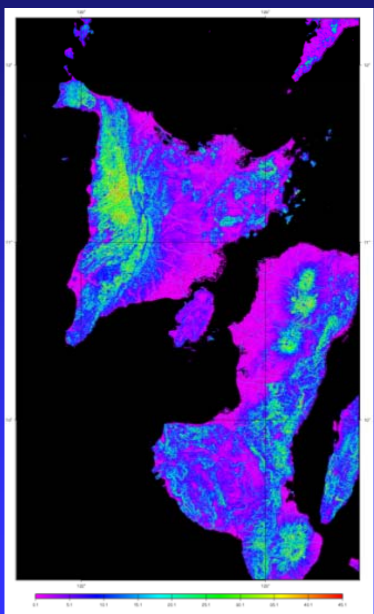
Generation of Site Amplification Map

Method of Allen and Wald, 2009

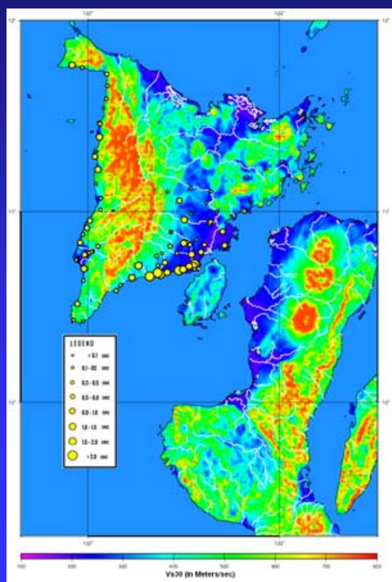
Topo MAp



Slope MAp

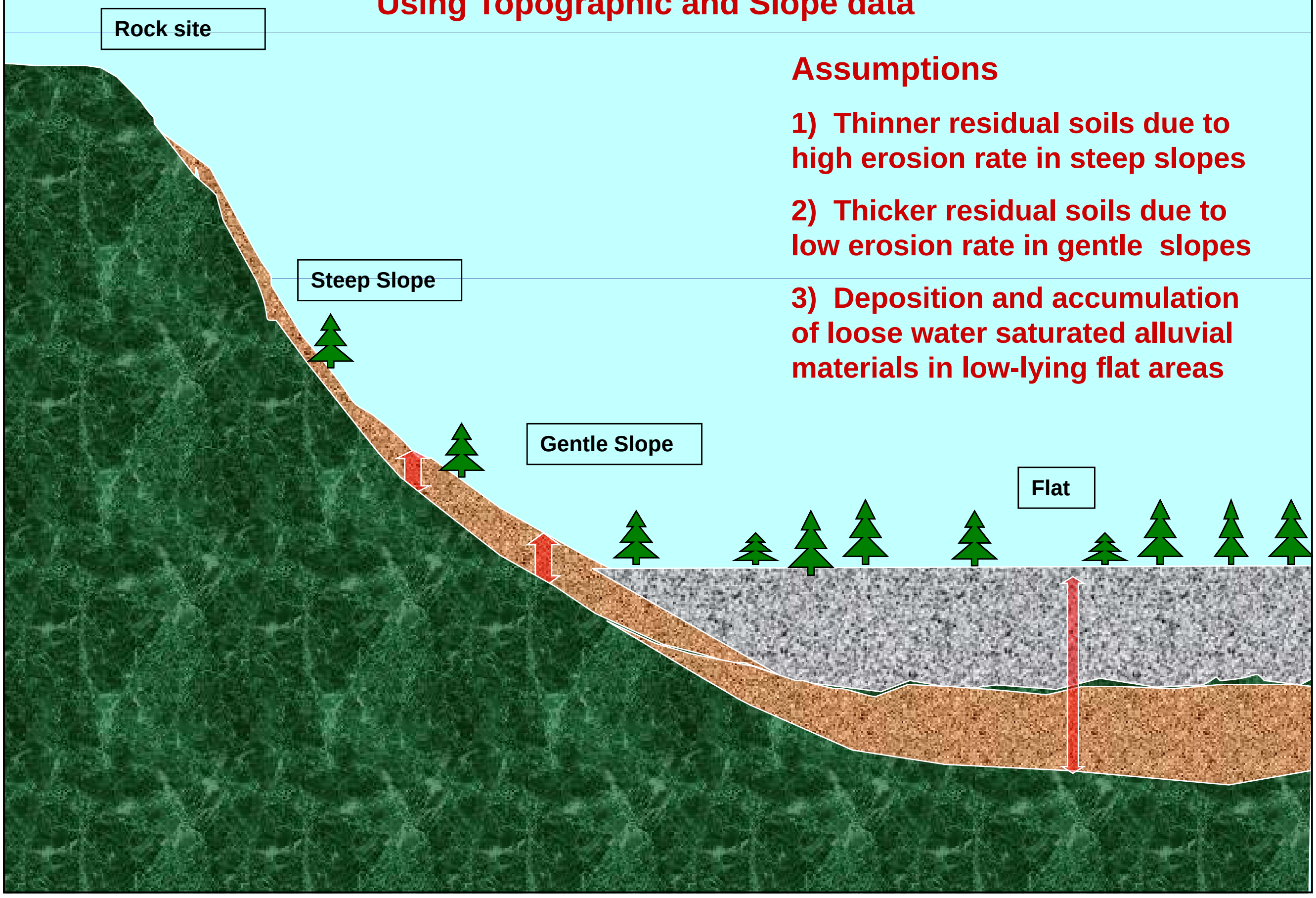


VS30 Map



Basis for Estimating Site Amplification

Using Topographic and Slope data



Assumptions

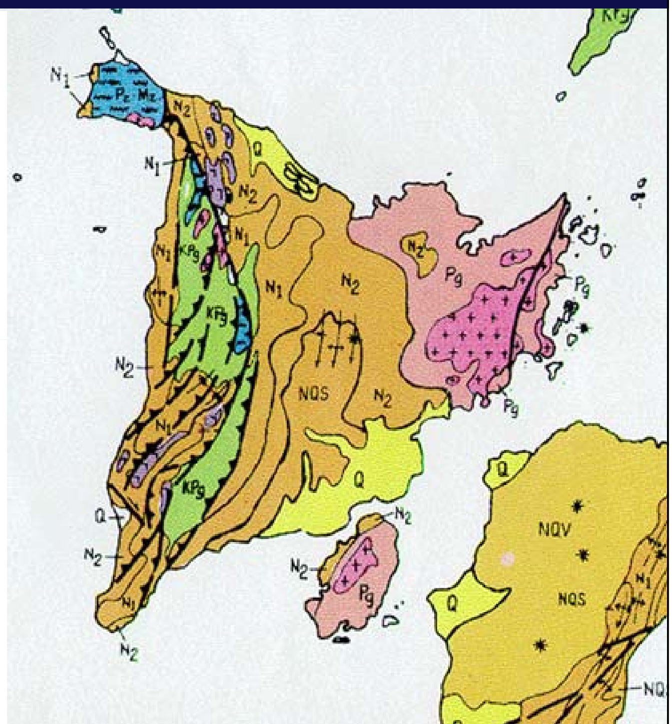
1) Thinner residual soils due to high erosion rate in steep slopes

2) Thicker residual soils due to low erosion rate in gentle slopes

3) Deposition and accumulation of loose water saturated alluvial materials in low-lying flat areas

GEOLOGICAL MAP

- Q — Quaternary alluvial, lacustrine, beach and residual deposits
- N_1 — Late Oligocene-Middle Miocene sediments and volcanics; marine ss,
- N_2 — Upper Miocene sediments and volcanics; largely marine clastics, reef ls & andesitic-basaltic pf and lv
- NQS — Pliocene to Pleistocene sediments (marine & terrestrial); includes extensive reef limestone & water-laid PF; alsolocalized terrace gravel deposits
- KPg — Undifferentiated Cretaceous to Paleogene strata; metavolcanics and metasediments
- Basic & ultrabasic; mainly peridotite, dunite (generally serpentinized) & layered gabbro; troctolite, norite, trondjhemite
- Pz-Mz — Carboniferous to Middle Jurassic radiolarite, sandstone, shale, limestone and conglomerate
- Intermediate to acid; mainly diorite, granodiorite, quartz diorite and monzonite

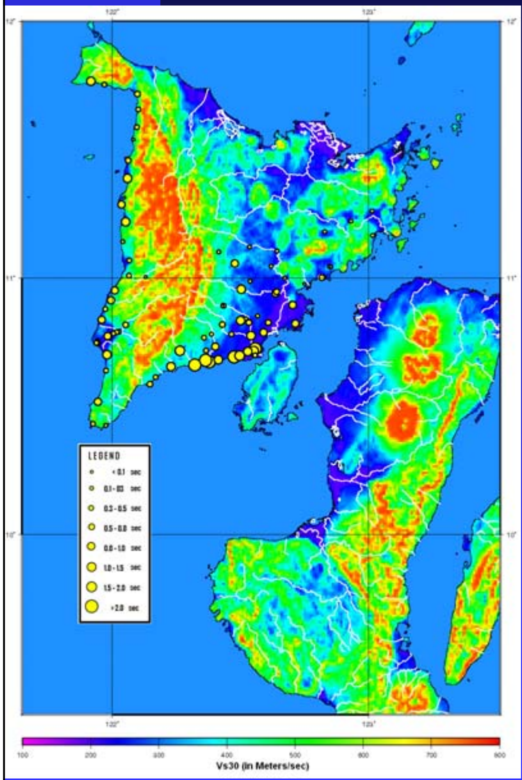


Source: Mines and Geosciences Bureau-DENR

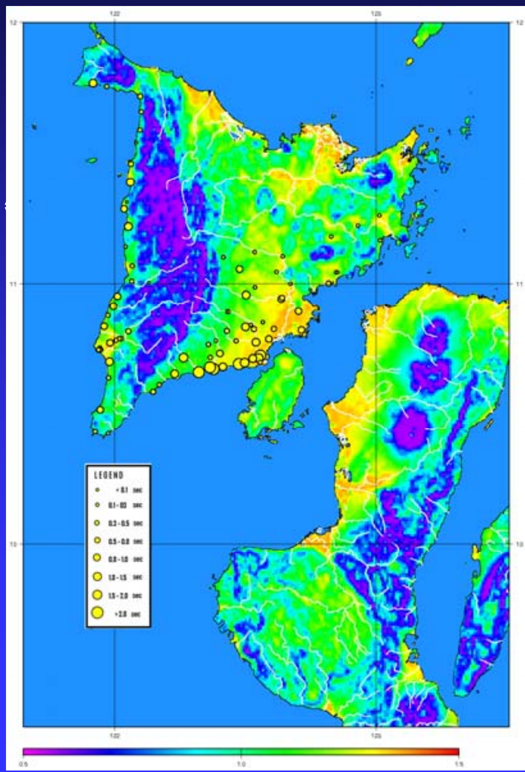
Liquefaction Hazard Mapping. Antique Province– 11.18 to 11.28.2009

Generation of Site Amplification Map (Method 2)

PAGER Vs30 Map



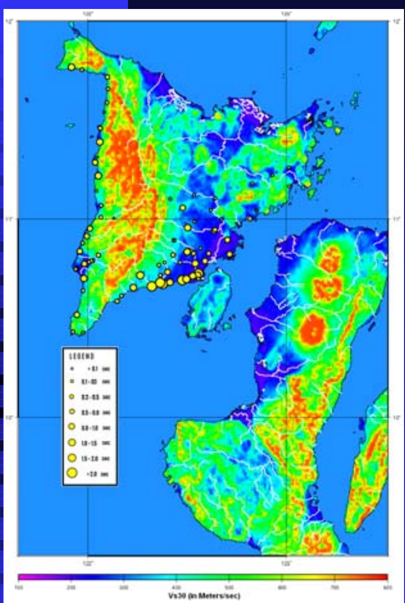
Amplification Map



Amp = -0.0014 (vs30) + 1.6357

From Allen and Wald, 2009

Microtremor H/V measurement



Microtremor Period VS Sediment Thickness

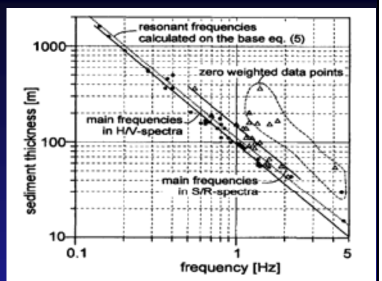


Figure 7. Main frequencies in spectral ratios plotted versus sediment thickness (solid circles: H/V frequencies; triangles: S/R frequencies). The solid lines are fits to the data points (see equation 9). The dashed line is the theoretical dependence between thickness and resonant frequency (see equation 5).

From Malte Ibs-von Seht and Jtirgen Wohlenberg

Bulletin of the Seismological Society of America, Vol. 89, No. 1, pp. 250-259, February 1999

Nakamura Microtremor method

SR=H / V

SR=Site response Spectra
H= Average spectra of the two horizontal components
V = Spectra of the vertical component

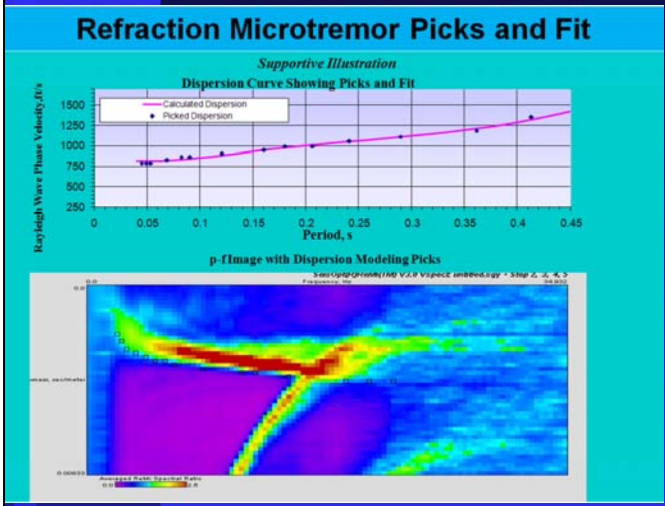
Fo = Cs / 4D

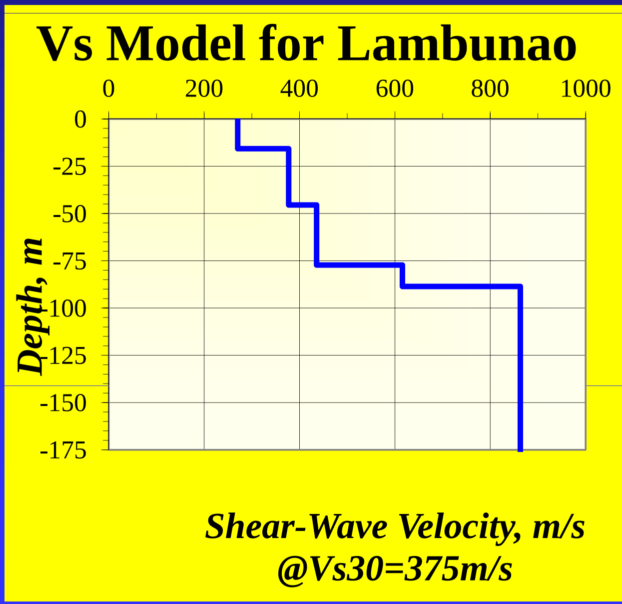
Fo=predominant Frequency which is obtained for SR
Cs=shear-wave velocity of surface sediments
D=depth of basement rock

Ao=Cb / Cs

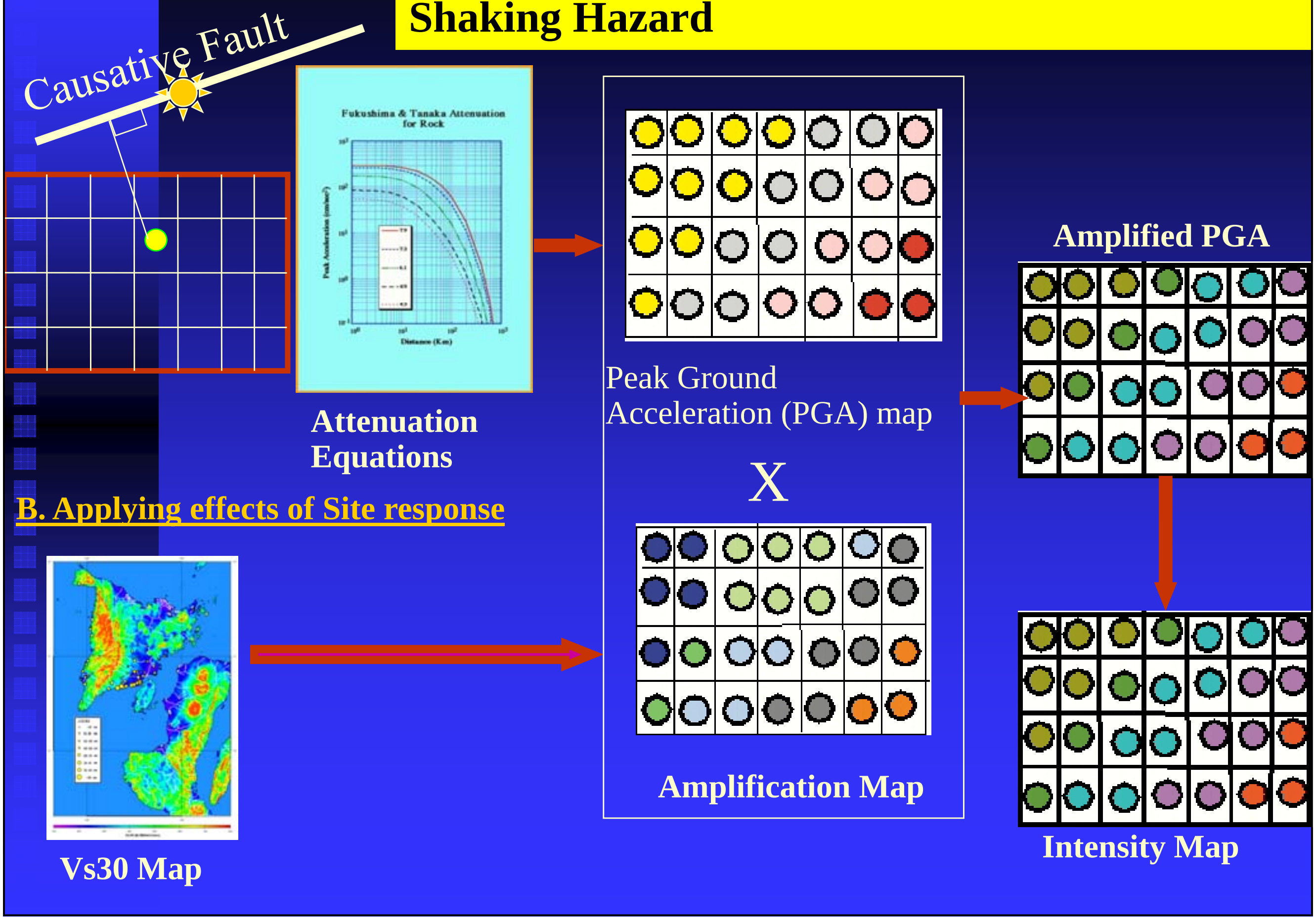
Ao=amplification factor related to impedeance
Cb=shear-wave velocity of basement rock

Refraction Microtremor (REMI) Sample Results

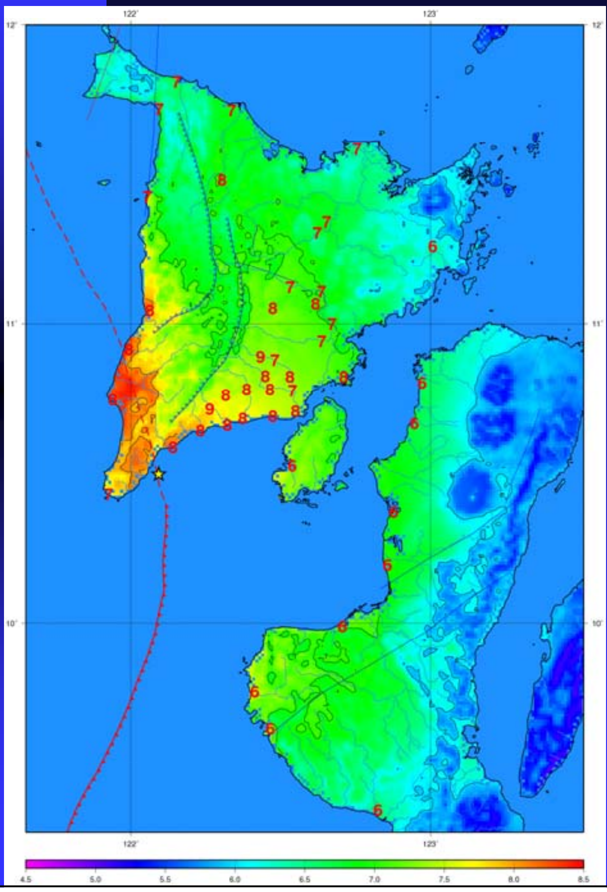




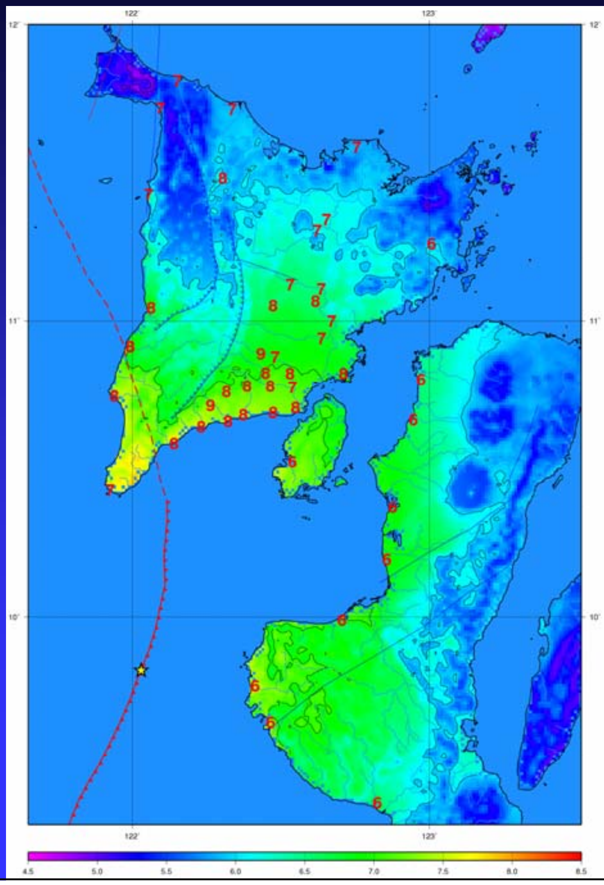
Determistic Method of Estimating Ground Shaking Hazard



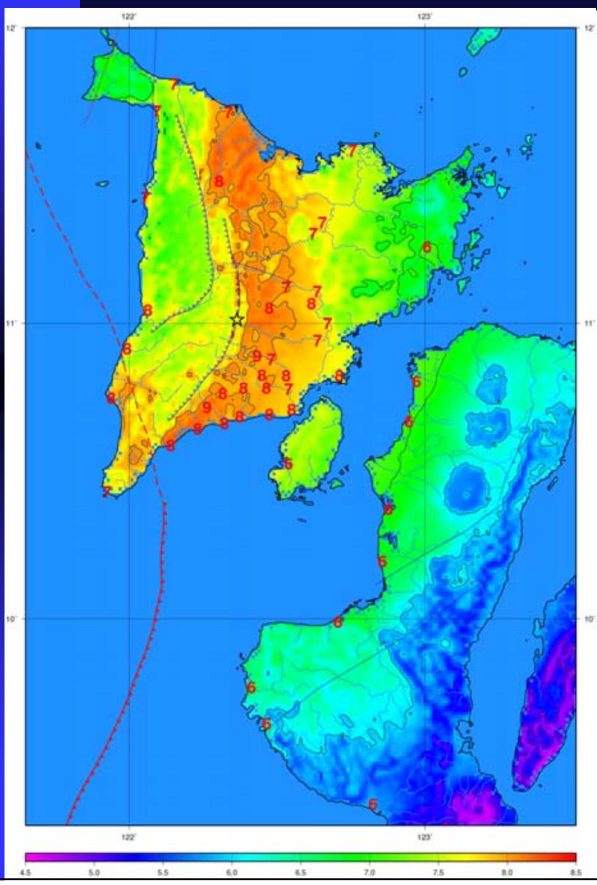
Scenario 1



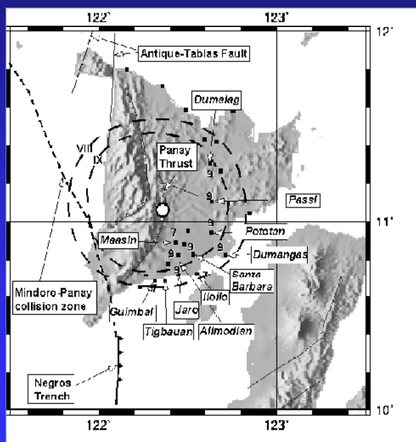
Scenario 2



Scenario 3



Scenario 3 explains well the distribution of damages incurred during the 1948 Panay Island Earthquke



Isoseismal map of the 1787 July 13 earthquake (6:45 AM). Filled circle signifies estimated epicenter; filled squares are locations of known and established towns during this time. Italicized names are places mentioned in earthquake accounts. This is being related to the movement of the East Panay Thrust. Roman numbers are intensities in MMI. A(IX) is 5810 sq. km (Ms 7.5) and A(VIII) is 9010 sq. km (Ms 7.3). Ms(ave) is 7.4.

Conclusion and Recommendation

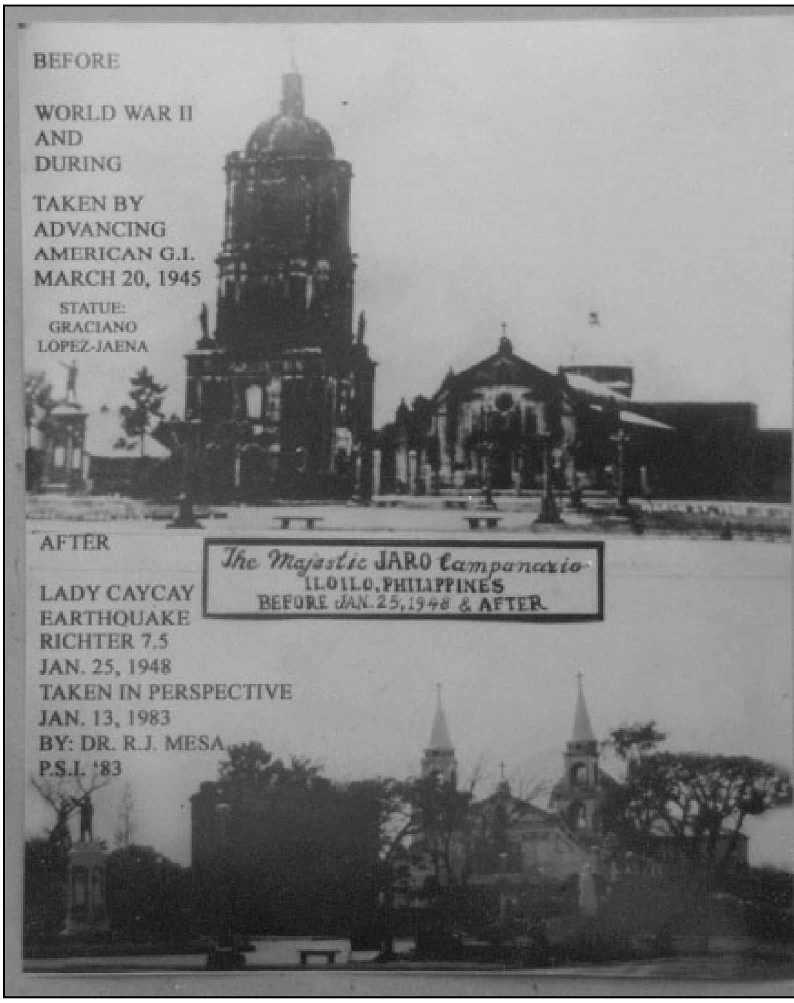
- The results of the study showed that the most appropriate source is along an active thrust fault located 30 km west of Iloilo City (Scenario 3).
- Not much information was obtained about tsunami which means that it is probably too small and did not cause any serious damage.
- More eyewitness interviews and intensity surveys in Northern Panay and Negros Island need to be done to improve damage distribution.
- More microtremor measurements in Northern Panay and Negros Island to enhance site amplification data.
- Consider directivity in intensity simulations
- Paleoseismic study of the fault is recommended to verify its latest movement and estimate the magnitude and recurrence time of earthquakes

Thank You
For
Listening

Eye Witness Interview

Miag-ao, Iloilo:
- Miagao Church was damaged
- Tsunami killed fish when water receded
- Numerous long and wide fissures ("litik")

Earthquake Eyewitnesses from Miag-ao: Lilia Gecobe and Salvacion Tuale



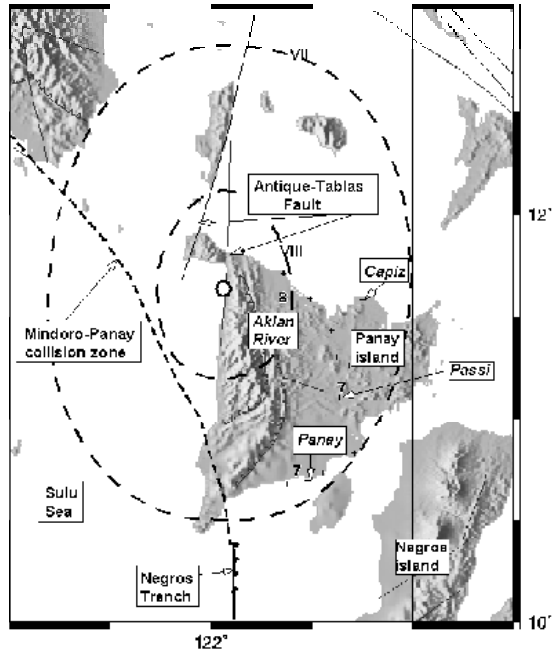
Before and After pictures of the Jaro Belfry in Iloilo City

photos courtesy of the Museo Iloilo

Jaro Belfry Today

The Earthquake of December 1621 (Mag 7.2)

- Aklan River: River changed course and left its old bed
- Passi, Iloilo: Stone church was badly damaged

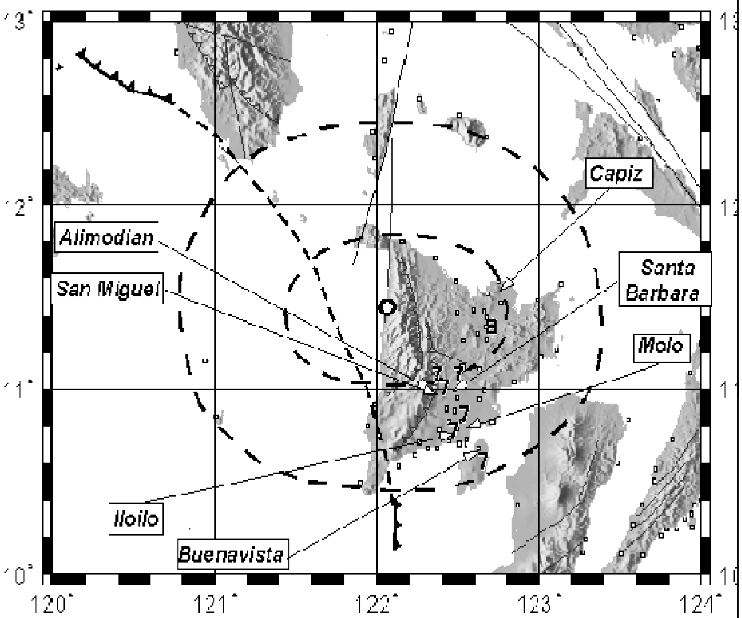


Isoseismal map of the 1621 December earthquake. Filled circle signifies estimated epicenter; crosses are locations of known and established towns during this time. Italicized names are places mentioned in earthquake accounts. This is being related to the movement of the Antique Tablas Fault. Roman numbers are intensities in MMI. A(VIII) is 6386 sq. km (Ms 7.2) and A(VII) is 43887 sq. km (Ms 7.2). Ms(ave) is 7.2.

References: Medina, 1630; Diaz, 1890; Blair and Robertson, 1903; Maso, 1927; Repetti, 1946; MLPBautista, 1999

The Earthquake of 1887 (Mag 7.3)

- Capiz – Chimneys broke, violently felt
- Iloilo City - Wall of Custom House and a partition wall of the Church fell
- Santa Barbara,Alimodian,San Miguel,Molo (Iloilo) and Buenavista (Guimaras) – Churches were damaged and façade fell
- Sea waves were observed



Isoseismal Map of the 1887 February 2 earthquake (11:00 PM). Filled circle signifies estimated epicenter; filled squares are locations of known and established towns during this time. Italicized names are places mentioned in earthquake accounts. Roman numbers are intensities in MMI. This is being related to the activity of the Antique-Tablas Fault. A(VIII) is 11361 sq. km (Ms 7.3) and A(VII) is 52765 sq. km (Ms 7.3). Ms(ave) is 7.3.

References: Porvenir de Visayas, ----; El Eco, ----; Maso, 1895, 1904; Repetti, 1946; Heck, 1947;MLPBautista, 1999