

Searching for Old Tsunamis and Earthquakes in Banda Aceh and the Application of INQUA Intensity Scale

G.M. Besana-Ostman*, M. Ando, F.
Kimata, M. Umitsu, T. Tanaka, F.
Kimura, D. Sugiyanto, M. Takahashi,
and Suhirman

Nagoya University, Syah Kuala University, and
Bandung Institute of technology

**Now at*

University of North Carolina, Chapel Hill

The Research Team



KOPOLDAKRIKOR REPUBLIK INDONESIA
DIREKSI KASABANDARA ASIN-DARUSALAM
DIREKTORAT INTELAM

SURAT YANDA MELAPORKAN
CERTIFICATE OF POLICE REGISTR
NO.POL. STMPOL-4783006-DIT 9

1. NAMA: FAREZ M. LAM, ST. M. S. 2. ALAMAT: J.A. PRADA 1 L. SELAMANDI 30
3. JENJANG: DOSEN FT UNYOH 4. JENJANG: DOSEN FT UNYOH
5. JENJANG: 27 FEBRUARI 2006 6. JENJANG: 27 FEBRUARI 2006
7. JENJANG: 27 FEBRUARI 2006 8. JENJANG: 27 FEBRUARI 2006

TELAP MELAPORKAN TENTANG TAMU NAMA YANG MENYERAP DI: J.A. PRADA 1 L. SELAMANDI 30 BANDU AGO
HAS REPORTED THE FOREIGN GUEST STAYING IN:

1. NAMA: FAREZ M. LAM 2. ALAMAT: J.A. PRADA 1 L. SELAMANDI 30 BANDU AGO
3. JENJANG: DOSEN FT UNYOH 4. JENJANG: DOSEN FT UNYOH
5. JENJANG: 27 FEBRUARI 2006 6. JENJANG: 27 FEBRUARI 2006
7. JENJANG: 27 FEBRUARI 2006 8. JENJANG: 27 FEBRUARI 2006

TELAP MELAPORKAN TENTANG TAMU NAMA YANG MENYERAP DI: J.A. PRADA 1 L. SELAMANDI 30 BANDU AGO
HAS REPORTED THE FOREIGN GUEST STAYING IN:

1. NAMA: FAREZ M. LAM 2. ALAMAT: J.A. PRADA 1 L. SELAMANDI 30 BANDU AGO
3. JENJANG: DOSEN FT UNYOH 4. JENJANG: DOSEN FT UNYOH
5. JENJANG: 27 FEBRUARI 2006 6. JENJANG: 27 FEBRUARI 2006
7. JENJANG: 27 FEBRUARI 2006 8. JENJANG: 27 FEBRUARI 2006

TELAP MELAPORKAN TENTANG TAMU NAMA YANG MENYERAP DI: J.A. PRADA 1 L. SELAMANDI 30 BANDU AGO
HAS REPORTED THE FOREIGN GUEST STAYING IN:

1. NAMA: FAREZ M. LAM 2. ALAMAT: J.A. PRADA 1 L. SELAMANDI 30 BANDU AGO
3. JENJANG: DOSEN FT UNYOH 4. JENJANG: DOSEN FT UNYOH
5. JENJANG: 27 FEBRUARI 2006 6. JENJANG: 27 FEBRUARI 2006
7. JENJANG: 27 FEBRUARI 2006 8. JENJANG: 27 FEBRUARI 2006

KOPOLDAKRIKOR REPUBLIK INDONESIA
DIREKSI KASABANDARA ASIN-DARUSALAM
DIREKTORAT INTELAM

SURAT TANDA MELAPORKAN
CERTIFICATE OF POLICE REGISTRATION
NO.POL. STMPOL-4783006-DIT 10

1. NAMA: FAREZ M. LAM, ST. M. S. 2. ALAMAT: J.A. PRADA 1 L. SELAMANDI 30
3. JENJANG: DOSEN FT UNYOH 4. JENJANG: DOSEN FT UNYOH
5. JENJANG: 27 FEBRUARI 2006 6. JENJANG: 27 FEBRUARI 2006
7. JENJANG: 27 FEBRUARI 2006 8. JENJANG: 27 FEBRUARI 2006

TELAP MELAPORKAN TENTANG TAMU NAMA YANG MENYERAP DI: J.A. PRADA 1 L. SELAMANDI 30 BANDU AGO
HAS REPORTED THE FOREIGN GUEST STAYING IN:

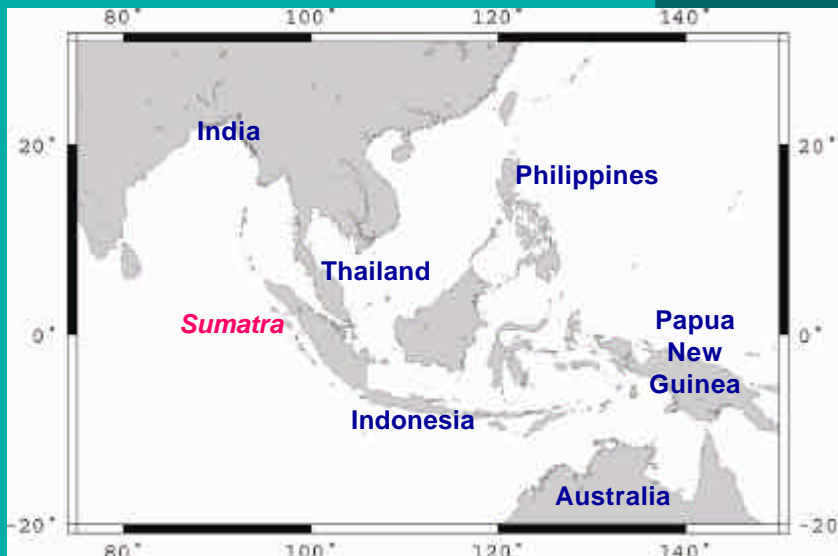
1. NAMA: FAREZ M. LAM 2. ALAMAT: J.A. PRADA 1 L. SELAMANDI 30 BANDU AGO
3. JENJANG: DOSEN FT UNYOH 4. JENJANG: DOSEN FT UNYOH
5. JENJANG: 27 FEBRUARI 2006 6. JENJANG: 27 FEBRUARI 2006
7. JENJANG: 27 FEBRUARI 2006 8. JENJANG: 27 FEBRUARI 2006

TELAP MELAPORKAN TENTANG TAMU NAMA YANG MENYERAP DI: J.A. PRADA 1 L. SELAMANDI 30 BANDU AGO
HAS REPORTED THE FOREIGN GUEST STAYING IN:

1. NAMA: FAREZ M. LAM 2. ALAMAT: J.A. PRADA 1 L. SELAMANDI 30 BANDU AGO
3. JENJANG: DOSEN FT UNYOH 4. JENJANG: DOSEN FT UNYOH
5. JENJANG: 27 FEBRUARI 2006 6. JENJANG: 27 FEBRUARI 2006
7. JENJANG: 27 FEBRUARI 2006 8. JENJANG: 27 FEBRUARI 2006

TELAP MELAPORKAN TENTANG TAMU NAMA YANG MENYERAP DI: J.A. PRADA 1 L. SELAMANDI 30 BANDU AGO
HAS REPORTED THE FOREIGN GUEST STAYING IN:

1. NAMA: FAREZ M. LAM 2. ALAMAT: J.A. PRADA 1 L. SELAMANDI 30 BANDU AGO
3. JENJANG: DOSEN FT UNYOH 4. JENJANG: DOSEN FT UNYOH
5. JENJANG: 27 FEBRUARI 2006 6. JENJANG: 27 FEBRUARI 2006
7. JENJANG: 27 FEBRUARI 2006 8. JENJANG: 27 FEBRUARI 2006



Magnitude	Magnitude 9.1 - OFF THE WEST COAST OF NORTHERN SUMATRA
Date-Time	<ul style="list-style-type: none"> •Sunday, December 26, 2004 at 00:58:53 (UTC) = Coordinated Universal Time •Sunday, December 26, 2004 at 7:58:53 AM = local time at epicenter Time of Earthquake in other Time Zones
Location	3.316°N, 95.854°E
Depth	30 km (18.6 miles) set by location program
Region	OFF THE WEST COAST OF NORTHERN SUMATRA
Distances	250 km (155 miles) SSE of Banda Aceh, Sumatra, Indonesia 300 km (185 miles) W of Medan, Sumatra, Indonesia 1260 km (780 miles) SSW of BANGKOK, Thailand 1590 km (990 miles) NW of JAKARTA, Java, Indonesia
Location Uncertainty	horizontal +/- 5.6 km (3.5 miles); depth fixed by location program
Parameters	Nst=276, Nph=276, Dmin=654.9 km, Rmss=1.04 sec, Gp= 29°, M-type=teleseismic moment magnitude (Mw), Version=U
Source	USGS NEIC (WDCS-D)
Event ID	Usslav

The study area & the Earthquake

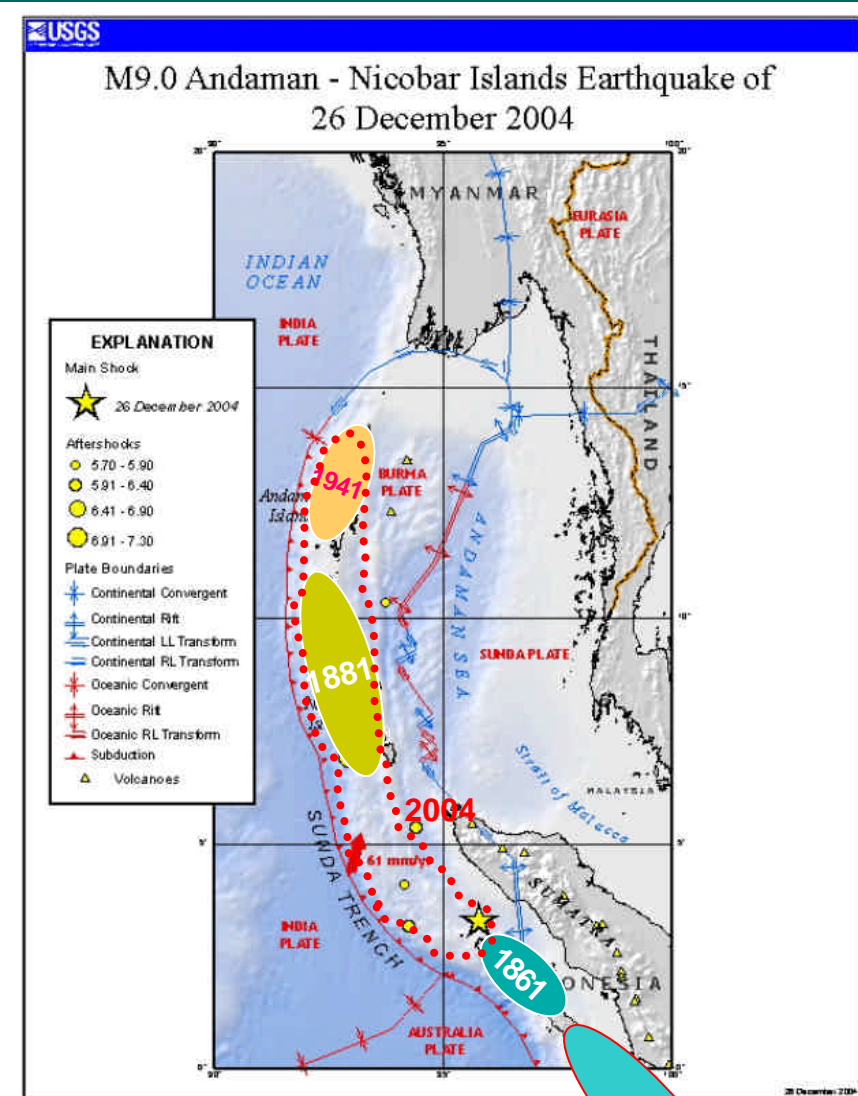
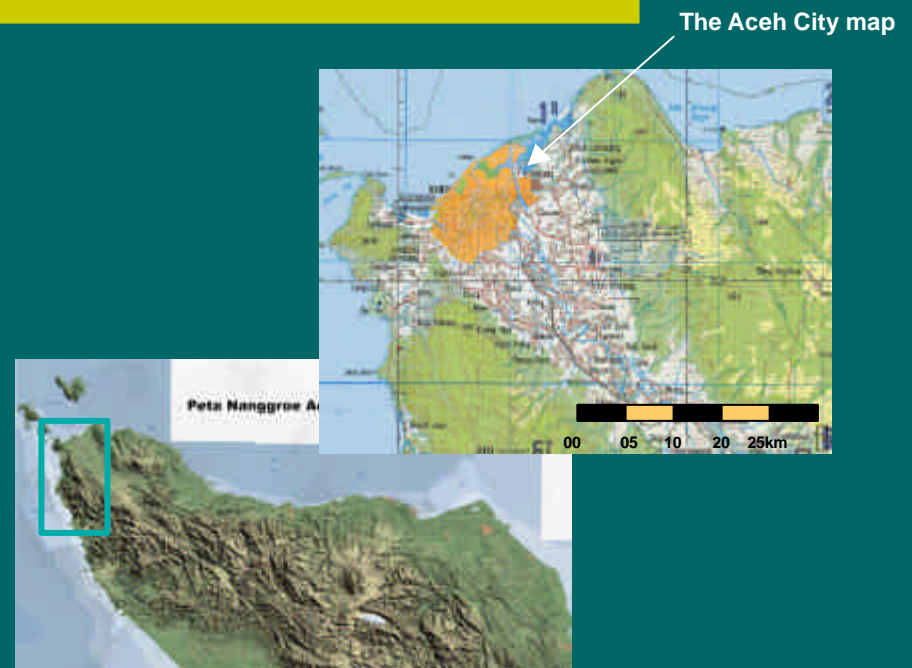


Figure 1. Epicenters of Main and After Shocks Earthquake following the tsunami in NAD and surrounding other countries in Asia [Source: USGS, 2004]

The Earthquake Investigation



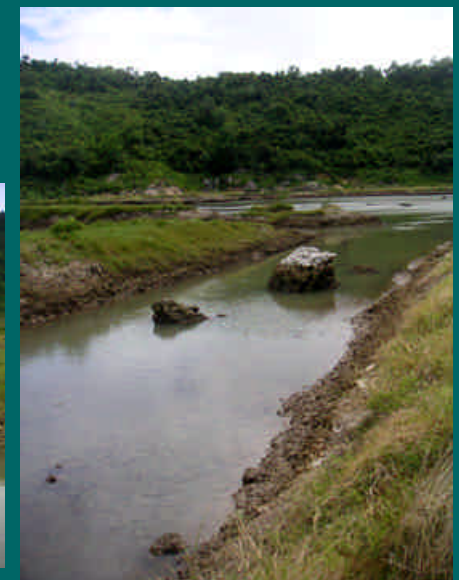
Philippine Earthquake Intensity Scale

IS	Description
I	Scarcely Perceptible - Perceptible to people under favorable circumstances. Delicately balanced objects are disturbed slightly. Still Water in containers oscillates slowly.
II	Slightly Felt - Felt by few individuals at rest indoors. Hanging objects swing slightly. Still Water in containers oscillates noticeably.
III	Weak - Felt by many people indoors especially in upper floors of buildings. Vibration is felt like one passing of a light truck. Dizziness and nausea are experienced by some people. Hanging objects swing moderately. Still water in containers oscillates moderately.
IV	Moderately Strong - Felt generally by people indoors and by some people outdoors. Light sleepers are awakened. Vibration is felt like a passing of heavy truck. Hanging objects swing considerably. Dinner, plates, glasses, windows and doors rattle. Floors and walls of wood framed buildings creak. Standing motor cars may rock slightly. Liquids in containers are slightly disturbed. Water in containers oscillate strongly. Rumbling sound may sometimes be heard.
V	Strong - Generally felt by most people indoors and outdoors. Many sleeping people are awakened. Some are frightened, some run outdoors. Strong shaking and rocking felt throughout building. Hanging objects swing violently. Dining utensils clatter and clink; some are broken. Small, light and unstable objects may fall or overturn. Liquids spill from filled open containers. Standing vehicles rock noticeably. Shaking of leaves and twigs of trees are noticeable.
VI	Very Strong - Many people are frightened; many run outdoors. Some people lose their balance. motorists feel like driving in flat tires. Heavy objects or furniture move or may be shifted. Small church bells may ring. Wall plaster may crack. Very old or poorly built houses and man-made structures are slightly damaged though well-built structures are not affected. <u>Limited rockfalls and rolling boulders occur in hilly to mountainous areas and escarpments. Trees are noticeably shaken.</u>
VII	Destructive - Most people are frightened and run outdoors. People find it difficult to stand in upper floors. Heavy objects and furniture overturn or topple. Big church bells may ring. Old or poorly-built structures suffer considerably damage. Some well-built structures are slightly damaged. <u>Some cracks may appear on dikes, fish ponds, road surface, or concrete hollow block walls. Limited liquefaction, lateral spreading and landslides are observed. Trees are shaken strongly.</u>
VIII	Very Destructive - People panicky. People find it difficult to stand even outdoors. Many well-built buildings are considerably damaged. Concrete dikes and foundation of bridges are destroyed by ground settling or toppling. Railway tracks are bent or broken. Tombstones may be displaced, twisted or overturned. Utility posts, towers and monuments may tilt or topple. Water and sewer pipes may be bent, twisted or broken. <u>Liquefaction and lateral spreading cause man-made structure to sink, tilt or topple. Numerous landslides and rockfalls occur in mountainous and hilly areas. Boulders are thrown out from their positions particularly near the epicenter. Fissures and faults rupture may be observed. Trees are violently shaken. Water splash or stop over dikes or banks of rivers.</u>
IX	Devastating - People are forcibly thrown to ground. Many cry and shake with fear. Most buildings are totally damaged. bridges and elevated concrete structures are toppled or destroyed. Numerous utility posts, towers and monument are tilted, toppled or broken. Water sewer pipes are bent, twisted or broken. <u>Landslides and liquefaction with lateral spreadings and sandboils are widespread. the ground is distorted into undulations. Trees are shaken very violently with some toppled or broken. Boulders are commonly thrown out. River water splashes violently on slops over dikes and banks.</u>
X	Completely Devastating - Practically all man-made structures are destroyed. <u>Massive landslides and liquefaction, large scale subsidence and uplifting of land forms and many ground fissures are observed. Changes in river courses and destructive seiches in large lakes occur. Many trees are toppled, broken and uprooted.</u>

Tsunami Boulders



Lhok Nga and Lhong



Tsunami Deposit



Lhok Nga



Old Tsunami Deposit?



Tsunami Inundation Effects



Krueng Raya

~5.0m



~4.0m



~2.5.0m

Tsunami Inundation Effects



~5.0m



Aceh Besar

columns bent along 106° azimuth



Trees and columns were bent along 205° azimuth



Tsunami Inundation Effects

~3.0m

Trees and columns were bent
along 205° azimuth

Lambaro Angan



Tsunami Inundation Effects



~10.0m

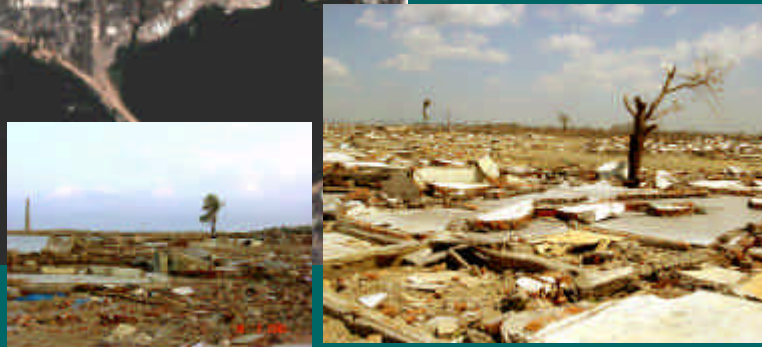
Ulee Lheue

Columns bent along 180° azimuth



Houses and coconut trees were swept away by the tsunami

~4.0m

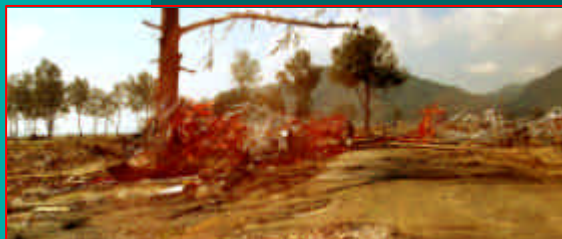


Substantial erosional effects

Tsunami Inundation Effects



Lhok Nga



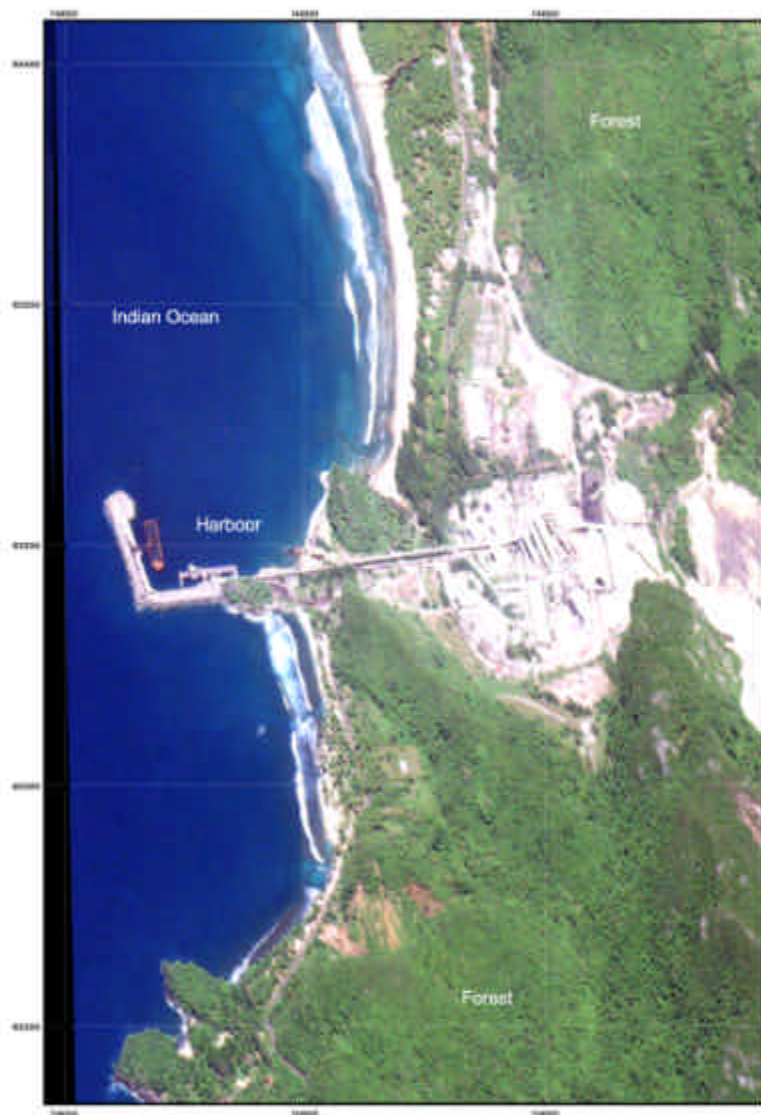
~12.0m



Tsunami Inundation Effects

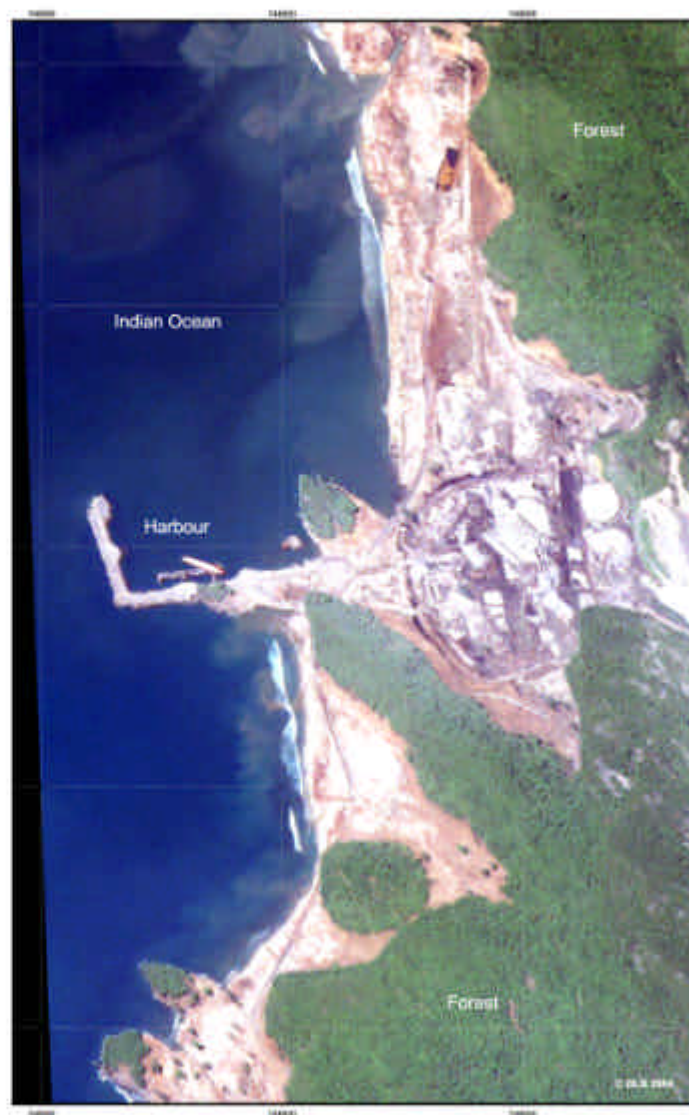
Indonesia - Banda Aceh Subset 4

IKONOS - January 10, 2003 - PRE-DISASTER IMAGE



1 : 5000

IKONOS - December 29, 2004 - POST-DISASTER IMAGE



Center for Satellite based
Crises Information
- Change to Mapping & Disaster Monitoring -

German Remote Sensing Data Center
German Aerospace Establishment

Legend

The map shows a moving and progressing zone with a harbour in the area of Banda Aceh on the island of Sumatra. (Indicated before and after the devastating Tsunami Road area, which struck many countries in the Indian Ocean on December 26, 2004.)

The IKONOS images were taken on January 10, 2003 and December 29, 2004, respectively.

The map shows the destruction caused by the Tsunami. The entire map and processing were done at the German Aerospace Establishment. In the harbour area, a large ship was wrecked.

Scale

0 100 200 300 400 500

1 : 5000

Projection: UTM Zone 48 S
Datum: WGS 84
Units: Meter

Scale

IKONOS imagery provided through
Centre for Remote Imaging,
Sensing and Processing (CRISP)

SPACE
IMAGING
Remote Sensing Data Center

Map created December 30, 2004 by J. J. J. J.



Tsunami Inundation Effects



Citra Natural Color QuickBird
28 Desember 2004

Sumber : [DIGITALGLOBE](#)

Dicetak Ulang Oleh : [BANGFATJA-LAPAN](#)

Tsunami Flow Directions



~4.0m

Ground Shaking Effects

Aceh City



~3.0m

Ground Shaking Effects



Ground Shaking Effects



Ground Deformation



Ulee Lheue



~0.40m lower than previous sea level



Ground Deformation

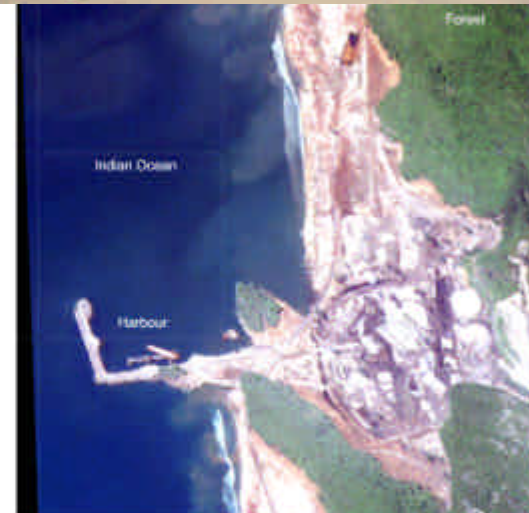
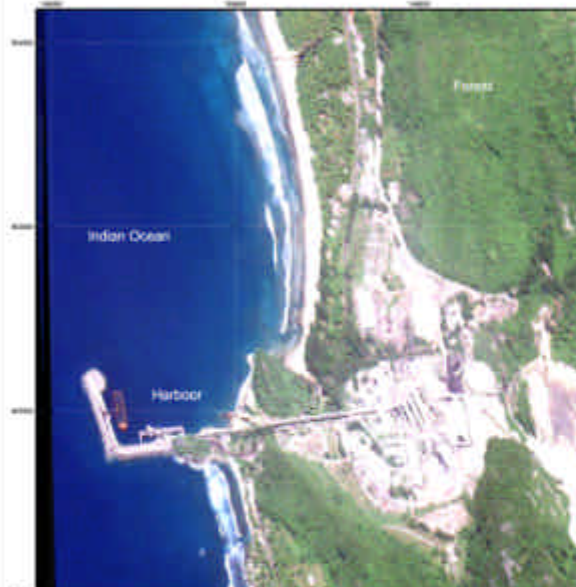


~12.0m



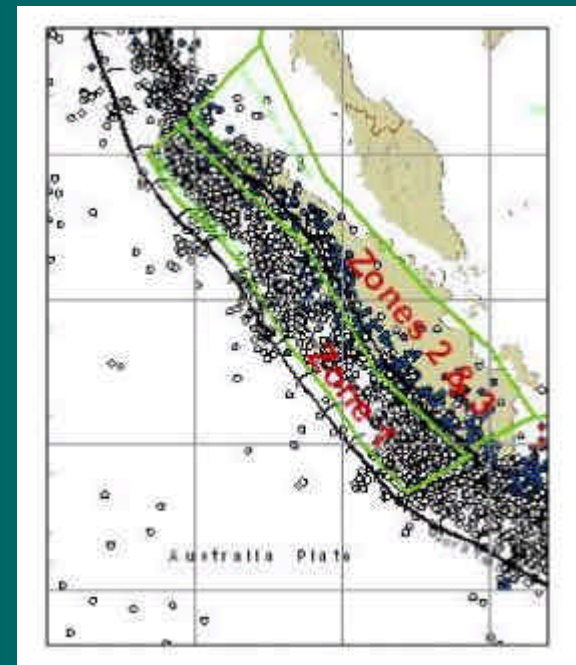
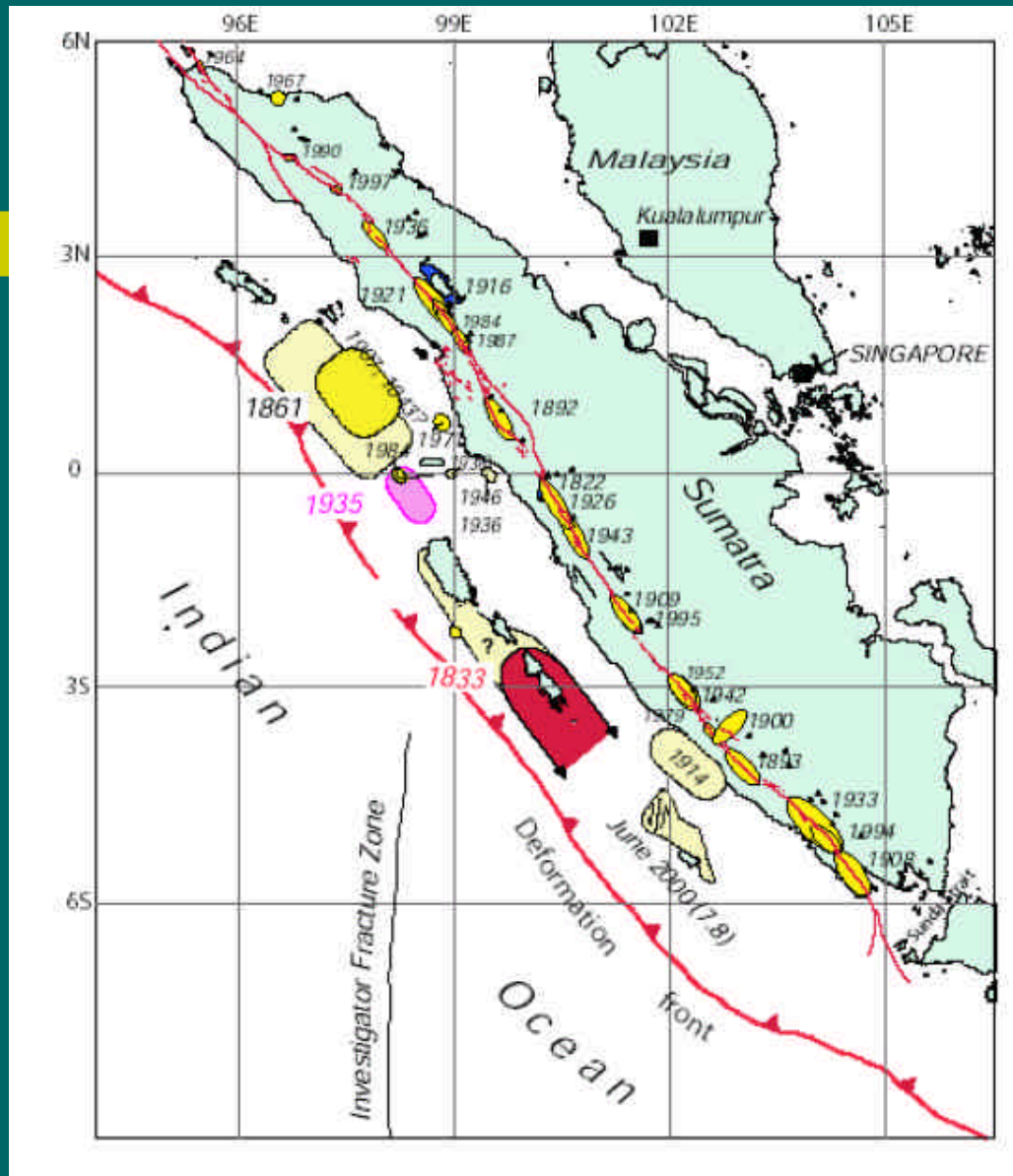
Indonesia - Banda Aceh Subset 4

IKONOS - January 10, 2003 - PRE-DISASTER IMAGE

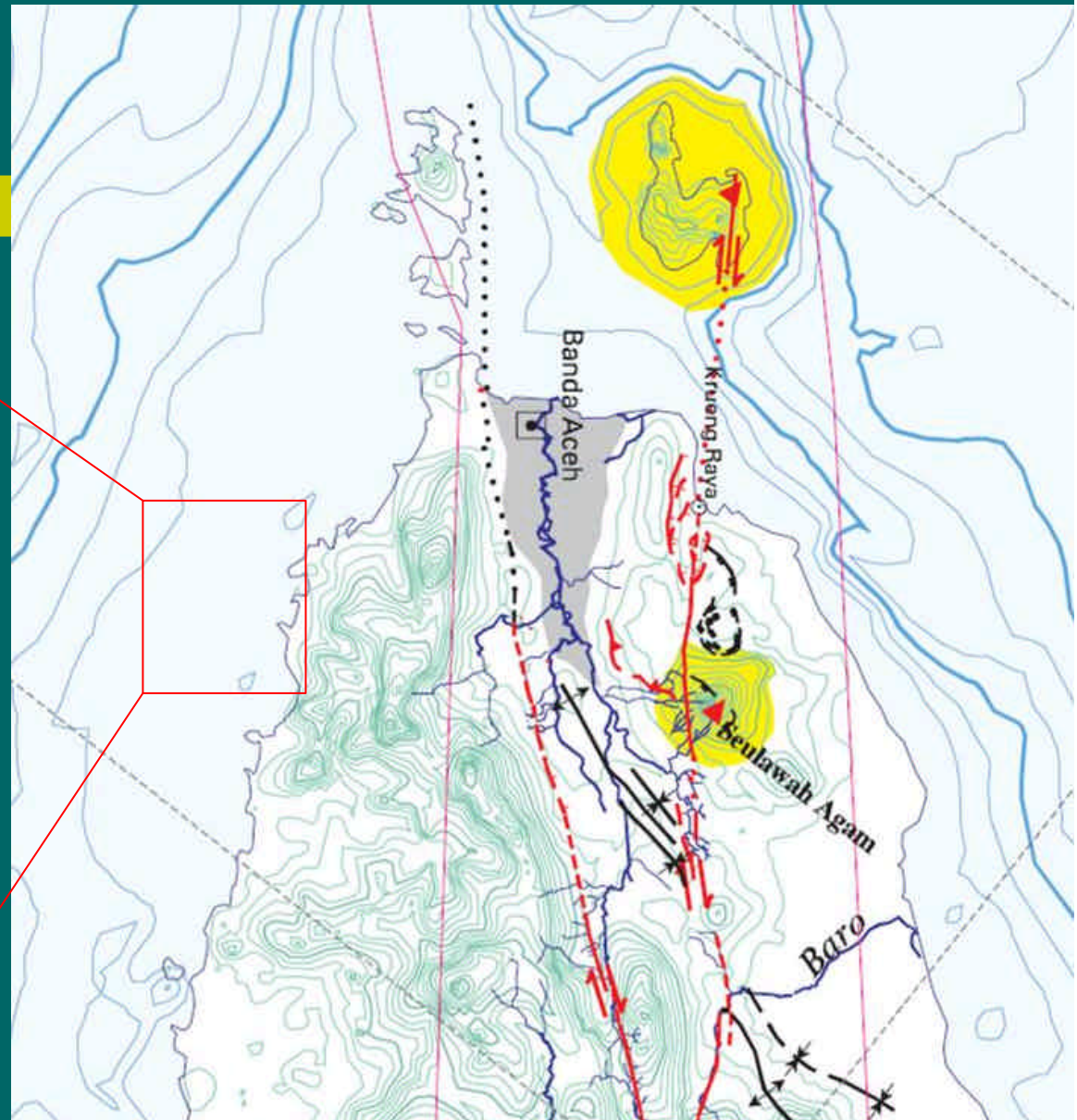


Remains of pine trees are currently submerged under sea water.

The Sumatra Fault



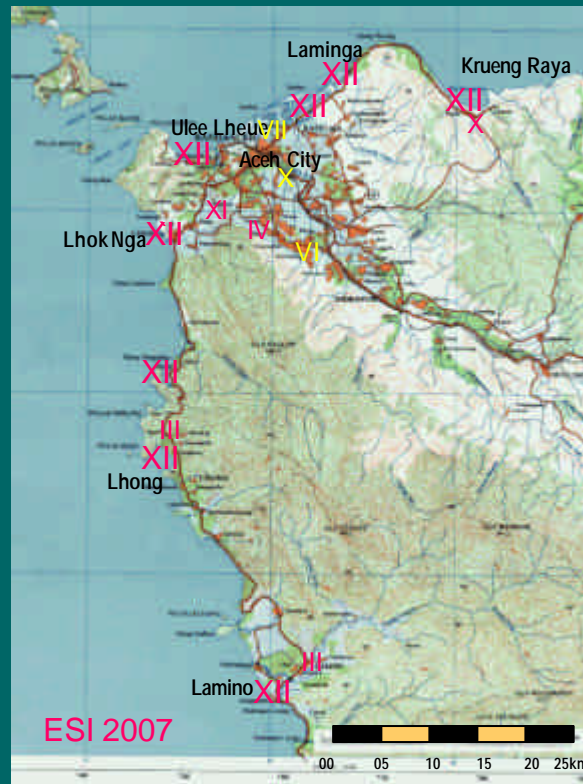
The Sumatra Fault



The Sumatra Fault



Intensities according to the ESI 2007 and PEIS 2002



Conclusions

- Tsunami height
- Tsunami inundation distance
- Affected structures
- Natural landforms
- Uplift vs. submergence vs. erosion
 - Line of oysters
 - Mangroves
 - Forests/pine trees
- Other previous giant tsunamis
- Long-term crustal deformation observations

Conclusions

- The ESI 2007 Form
 - Experience
 - Requests
 - Future works

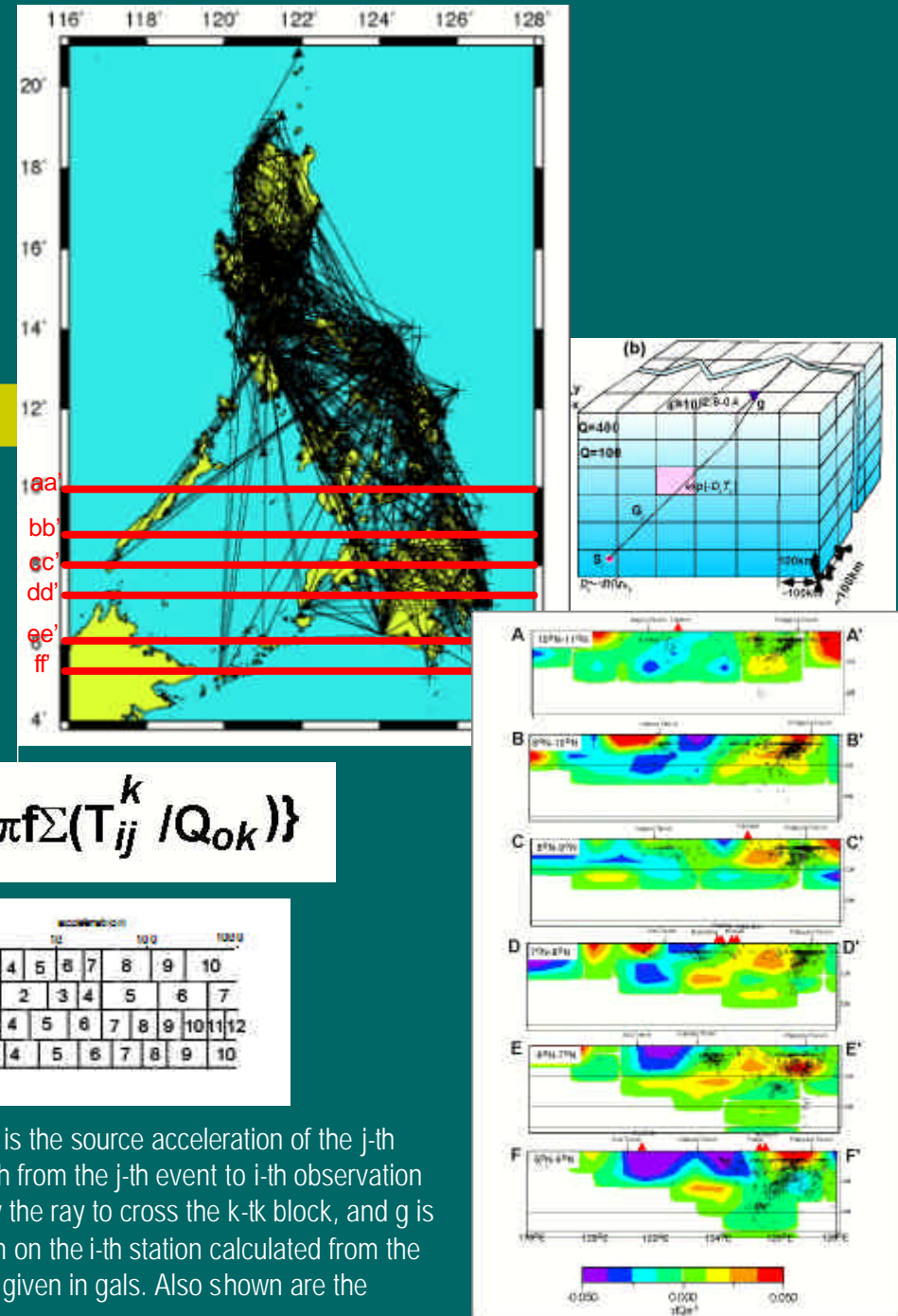
$$a_{ij}^{obs} = S_{ij} \cdot G_{ij} \cdot g \cdot \exp \{-\pi f \Sigma (T_{ij}^k / Q_{ok})\}$$

$$a = 10^{I/2.8 - 0.4}$$

RF = 100-200 acceleration

	acceleration									
	1	2	3	4	5	6	7	8	9	10
RF	1	2	3	4	5	6	7	8	9	10
JMA	0	1	2	3	4	5	6	7	8	9
MM	1	2	3	4	5	6	7	8	9	10
	1	2	3	4	5	6	7	8	9	10

Acceleration-intensity relation equation for the Philippines. S_{ij} is the source acceleration of the j-th event, G_{ij} represents the geometrical spreading along the path from the j-th event to i-th observation point, D_k is the attenuation coefficient, T_{ijk} is the time spent by the ray to cross the k-th block, and g is the site amplification factor. A_{ij}^{obs} is the observed acceleration on the i-th station calculated from the observed intensity I . Approximate values of acceleration a are given in gals. Also shown are the different intensity scales.





Thank you very much for your attention....

*"Our gratitude and thanks to the help support of all people of Banda Ache
and special thanks goes to Drs. Alessandro Michetti and Luca Guerri for
their encouragement and support."*