

*XVII INQUA Congress*

*Cairns, July 28th – August 3rd, 2007*

*Session 60 “Paleoseismology: linking Quaternary, historical and instrumental evidence of earthquake effects, and the ESI 2007 scale”*

# The Environmental Seismic Intensity scale – ESI 2007 Results and future directions



**Alessandro M. Michetti**  
**Università dell'Insubria, Como, Italy**  
**and the INQUA Scale Project Team**

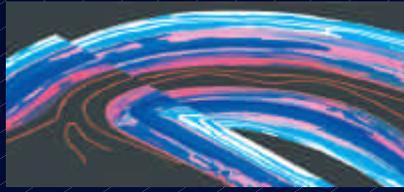
*XVII INQUA Congress*  
*Cairns, July 28th – August 3rd, 2007*  
*Session 60 “Paleoseismology and the ESI 2007 scale”*



**INQUA - ESI 2007 Scale Project Team**

**Sabina Porfido, Eliana Esposito**  
**Ruben Tatevossian, Eugene Rogozhin**  
**Takashi Azuma, Yoko Ota**  
**Leonello Serva, Aybars Guerpinar**  
**Luca Guerrieri, Eutizio Vittori**  
**Bagher and Jody Mohammadioun**  
**Shmulik Marco, Rifka Amit**  
**Amos Salamon, Valerio Comerci**  
**Jim McCalpin, Alan Nelson**  
**Sue Hough, George Papathanassiou**  
**Anna Fokaefs, Ioannis Papanikolaou**  
**Glenda Besana, Elisa Kagan**  
**Mohammed Abdel Aziz**  
**Nina Lin, Valerio Comerci,**  
**Claudia Lalinde, Silvia Mosquera,**  
**Yolanda Zamudio, Kervin Chunga,**

.....

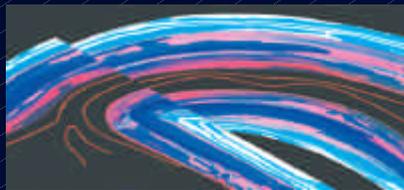


*XVII INQUA Congress*  
*Cairns, July 28th – August 3rd, 2007*  
*Session 60 “Paleoseismology and the ESI 2007 scale”*



## Summary of the presentation

1. Definition of earthquake intensity
2. Earthquake ground effects, dynamic source parameters and maximum magnitude determination – quality of data and resolution
3. Structure of the ESI 2007 scale, revised text and new guidelines: bringing physical phenomena (faulting, landsliding, tree and limb fall, water changes) in line with the damage indicators
4. New Madrid 1811, Assam 1897 and Anchorage 1964
5. Intensity, paleoseismology, Quaternary geology
6. The July 16, 2007, Niigata eq.
7. Future directions

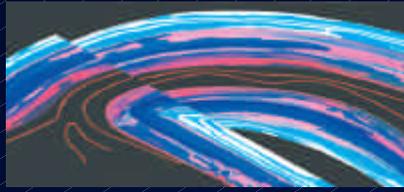


*XVII INQUA Congress*  
*Cairns, July 28th – August 3rd, 2007*  
*Session 60 “Paleoseismology and the ESI 2007 scale”*



## 1. INTENSITY: ORIGIN AND DEFINITIONS

Well before the introduction, in 1935 by Charles Richter, of the notion of “magnitude” based on measurements made on instrumentally-recorded motion, certain erudite seismologists (in the persons of Mercalli, Cancani, and Sieberg, among others), in the early years of the last century, devised the notion of the “intensity” of an earthquake at a given location, in the absence of any seismometer (e.g., Mercalli, 1897; Omori, 1900; Cancani, 1904; Sieberg, 1930; Wood and Neumann, 1931).



*XVII INQUA Congress*  
*Cairns, July 28th – August 3rd, 2007*  
*Session 60 “Paleoseismology and the ESI 2007 scale”*



## Mercalli, Omori, Sieberg and the formal definition of intensity

- ❖ INTENSITY is a parameter intended to quantify the effects of the earthquake, **ESPECIALLY HISTORICAL EARTHQUAKES**, at a site based on both “shaking effects” and “primary tectonic effects”.
- ❖ MOST OF THE “MERCALLI”-DERIVED SCALES ARE 12 DEGREE SCALES
- ❖ The effects on humans are the most important indicators of intensity up to the V degree. The assessment of intensity in the range between the VI and XII degree is based mostly on effects on man-made structures (damage) AND ON THE ENVIRONMENT (ground effects or environmental earthquake effects, EEE). Also in the Omori scale, the highest degrees are defined based on geological effects.

I. People do not feel any Earth movement.

II. A few people might notice movement if they are at rest and/or on the upper floors of tall buildings.

III. Many people indoors feel movement. Hanging objects swing back and forth. People outdoors might not realize that an earthquake is occurring.

IV. Most people indoors feel movement. Hanging objects swing. Dishes, windows, and doors rattle. The earthquake feels like a heavy truck hitting the walls. A few people outdoors may feel movement. Parked cars rock.

V. Almost everyone feels movement. Sleeping people are awakened. Doors swing open or close. Dishes are broken. Pictures on the wall move. Small objects move or are turned over. Trees might shake. Liquids might spill out of open containers.

VI. Everyone feels movement. People have trouble walking. Objects fall from shelves. Pictures fall off walls. Furniture moves. Plaster in walls might crack. Trees and bushes shake. Damage is slight in poorly built buildings. No structural damage.

VII. People have difficulty standing. Drivers feel their cars shaking. Some furniture breaks. Loose bricks fall from buildings. Damage is slight to moderate in well-built buildings; considerable in poorly built buildings.

VIII. Drivers have trouble steering. Houses that are not bolted down might shift on their foundations. Tall structures such as towers and chimneys might twist and fall. Well-built buildings suffer slight damage. Poorly built structures suffer severe damage. Tree branches break. Hillsides might crack if the ground is wet. Water levels in wells might change.

IX. Well-built buildings suffer considerable damage. Houses that are not bolted down move off their foundations. Some underground pipes are broken. The ground cracks. Reservoirs suffer serious damage.

X. Most buildings and their foundations are destroyed. Some bridges are destroyed. Dams are seriously damaged. Large landslides occur. Water is thrown on the banks of canals, rivers, lakes. The ground cracks in large areas. Railroad tracks are bent slightly.

XI. Most buildings collapse. Some bridges are destroyed. Large cracks appear in the ground. Underground pipelines are destroyed. Railroad tracks are badly bent.

XII. Almost everything is destroyed. Objects are thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move.

**Modified Mercalli scale, simplified**

## SCALA DELLE INTENSITA'

**I:** Scossa non percepibile, registrata solo dai sismografi



**II:** Scossa leggermente percepibile



**III:** Scossa flebilmente percepita



**IV:** Scossa percepita dalla maggioranza delle persone



**V:** Panico. Risveglio anche delle persone addormentate



**VI:** Fragore e panico generale. Danni lievissimi alle costruzioni (crepe negli intonaci e nelle pareti non portanti)



**VII:** Danni lievi alle costruzioni (crepe presenti anche nei muri portanti)



**VIII:** Distruzione di qualche edificio



**IX:** Distruzione di edifici e generale danneggiamento. Gli effetti sul terreno sono ben evidenti



**X:** Distruzione generale. Significativi effetti sul terreno



**XI:** Catastrofe. Grandi effetti sul terreno



**XII:** Grandiosi effetti sul terreno



## Basic structure of 12 degrees scales

MCS Scale

Mercalli – Cancani – Sieberg  
(1930)

Mostly used in S Europe

✓ Empirical scale, rating of earthquake effects are based on a rather subjective assessment, or expert judgement

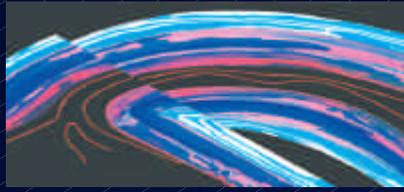
✓ Invaluable information, cannot be replaced by instrumental records

Epicentral intensity  $I_0 = XI$

Porfido et al., later today...

Isoseismal map of the June 5, 1688, Sannio earthquake (Serva, 1985) based on MCS scale





*XVII INQUA Congress  
Cairns, July 28th – August 3rd, 2007  
Session 60 “Paleoseismology and the ESI 2007 scale”*



**MM scale, 1931; intensity XII**

Damage total - practically all works of construction damaged greatly or destroyed.

Disturbances in ground great and varied, numerous shearing cracks. Landslides, falls of rock of significant character, slumping of river banks, etc. numerous and extensive. Wrenched loose, tore off, large rock masses.

**Fault slips in firm rock, with notable horizontal and vertical offset displacements.** Water channels, surface and underground, disturbed and modified greatly. Dammed lakes, produced waterfalls, deflected rivers, etc. Waves seen on ground surfaces (actually seen, probably, in some cases). Distorted lines of sight and level. **Threw objects upward into the air.**

*XVII INQUA Congress  
Cairns, July 28th – August 3rd, 2007  
Session 60 “Paleoseismology and the ESI 2007 scale”*

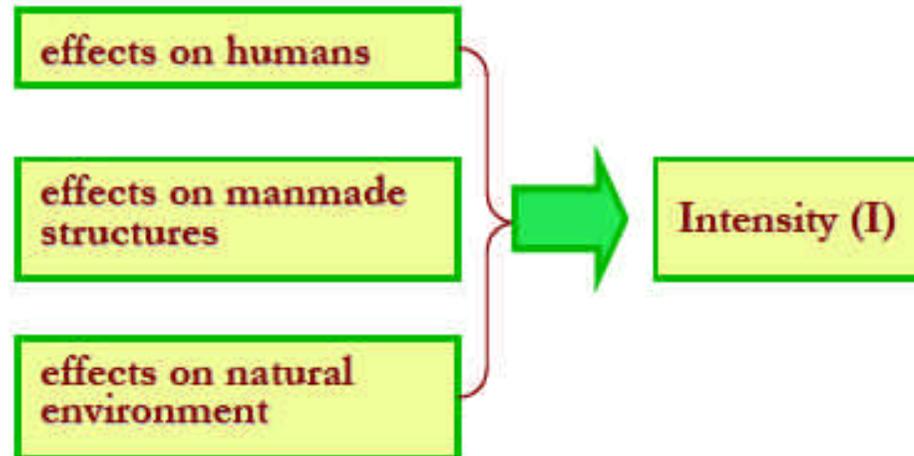


Fig. 1 - According to the original definition of intensity in the twelve degrees scales, i.e., the Mercalli-Cancani-Sieberg Scale (MCS), the Modified Mercalli scale (MM-31 and MM-56) and the Medvedev-Sponheuer-Karnik scale (MSK-64), the assessment of intensity degrees has to be based on humans, manmade structures and natural environment.  
- Secondo la definizione originale di intensità nelle scale a dodici gradi, quali la scala Mercalli-Cancani-Sieberg (MCS), la scala Mercalli Modificata (MM-31 e MM-56) e la scala Medvedev-Sponheuer-Karnik (MSK-64), la valutazione del grado di intensità deve essere basata sugli effetti sull'uomo, sulle strutture antropiche e sull'ambiente naturale.

## **Intensity concept (Ruben Tatevossian, 2007)**

**1) What we measure: effect itself or causa of effect via effect?**

**2) What reflects intensity? Is it an ill-defined analogue of PGA, or it reflects a phenomenon, which depends in a complex way on PGA, PGV, residual slip.**

**3) What is the subject of hazard assessment? (choice of site + seismic loading).**

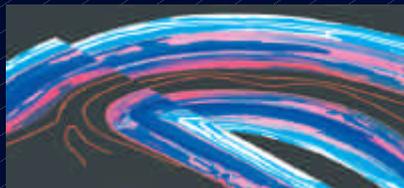
## Intensity concept

Further refinements of the macroseismic scales brought EMS98. It is a perfect tool to measure vibrational part of ground shaking but the basic concept was broken.

Intensity reflects a phenomenon depending in a complex way on PGA, PGV, and residual slip.

Excluding environmental effects violates this concept. But they should be treated in such a way, that intensity scale category will not be reduced to a ranking scale.

Such research helps promote our understanding of the earthquake history of a region, and estimate future hazards



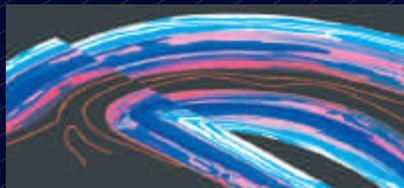
*XVII INQUA Congress*  
*Cairns, July 28th – August 3rd, 2007*  
*Session 60 “Paleoseismology and the ESI 2007 scale”*



## 2. ESI SCALE: A BETTER LINK TO DYNAMIC SOURCE PARAMETERS AND MMAX DETERMINATION, A BETTER TOOL FOR SITING

Intensity is a measure of the earthquake based on human perceptions, damage (buildings/man made structures), and the impact on the natural environment, which is the cumulative, final EFFECT from

- the SOURCE
  - VIBRATIONS generated during slip
  - FINITE DEFORMATIONS
- the PROPAGATION of seismic waves
- the local SITE CONDITIONS

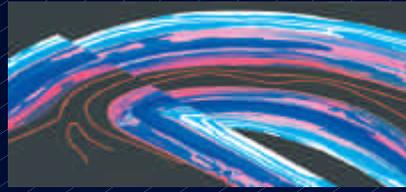


*XVII INQUA Congress*  
*Cairns, July 28th – August 3rd, 2007*  
*Session 60 “Paleoseismology and the ESI 2007 scale”*



The definition of intensity **IN THE NEAR FIELD OF STRONG EARTHQUAKES** is essentially based on the study of natural effects, since indicators based on human perception and damage **HAVE BEEN DESIGNED** by the Authors to saturate (“damage total”...) at intensity higher than IX in the MCS, MM1931, MM1958, and MSK scales

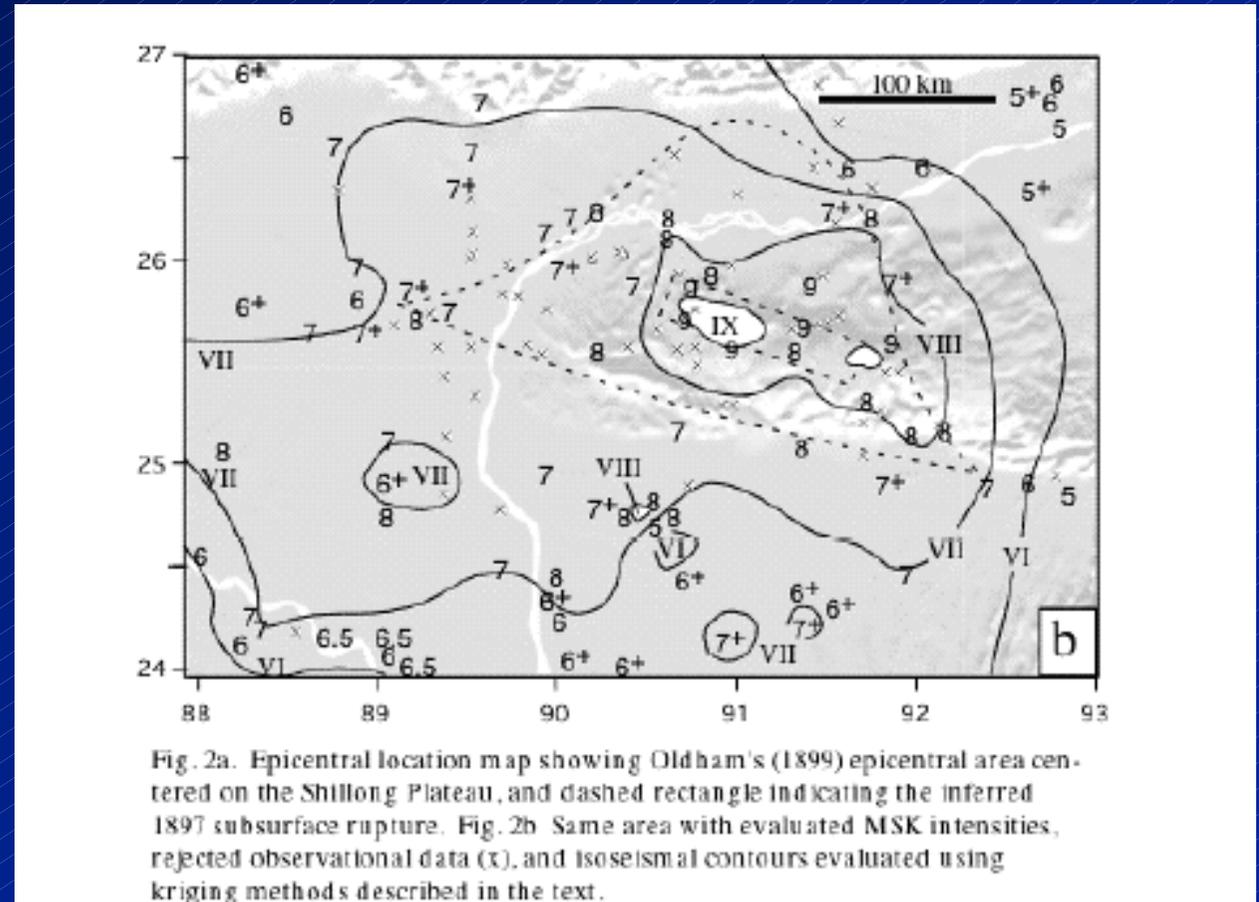
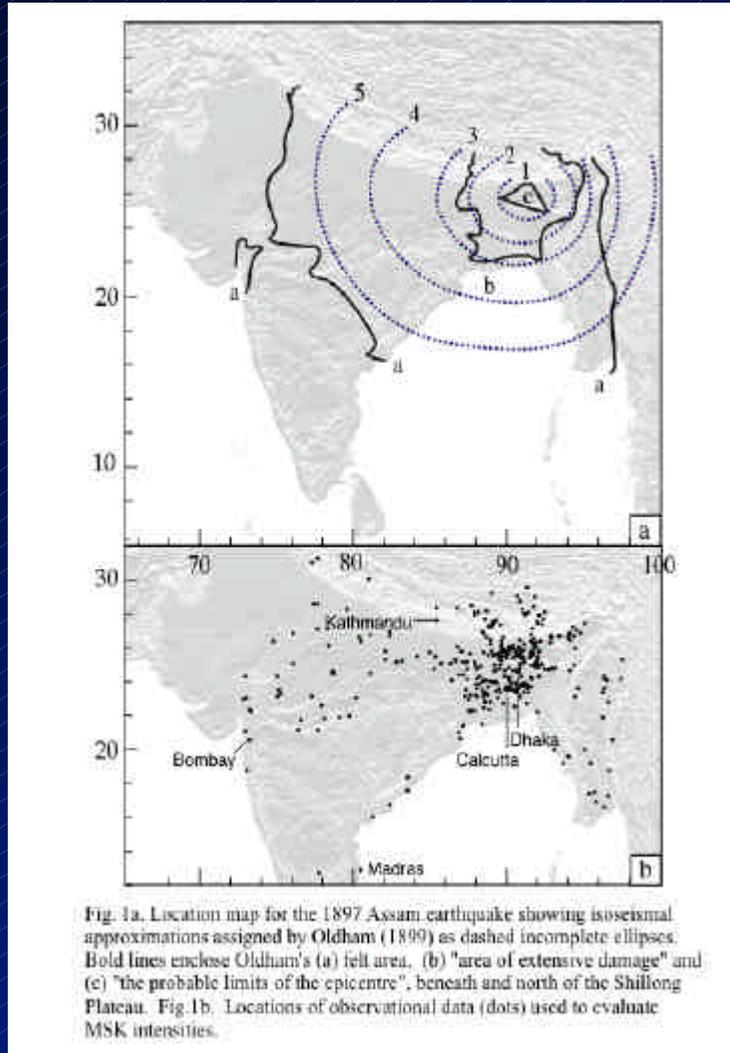
If we do not use environmental effects, as in the case of the EMS scale, the original concept of intensity is broken, and intensity X, XI and XII cannot be assessed anymore. A recent example...

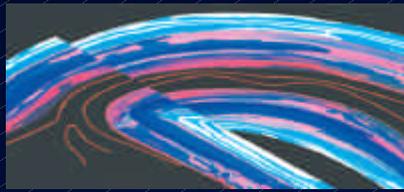


**XVII INQUA Congress**  
**Cairns, July 28th – August 3rd, 2007**  
**Session 60 “Paleoseismology and the ESI 2007 scale”**



**12 June 1897, M8+ Assam earthquake**  
**Revised by Ambraseys and Bilham (2003)**

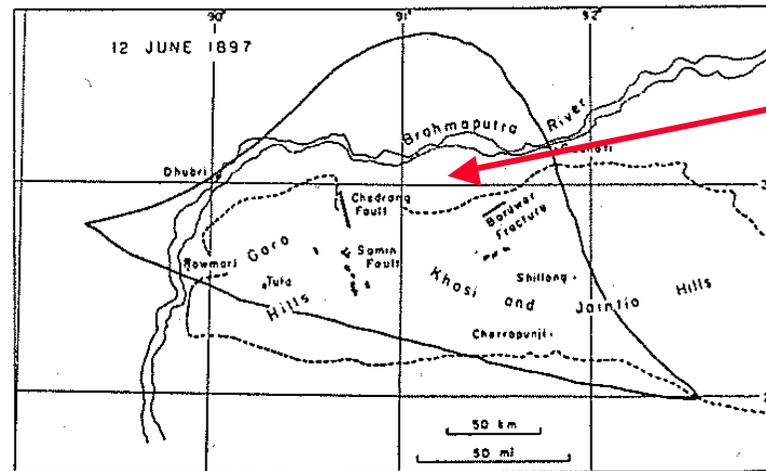




### *Isoseismals and Magnitude*

Figure 5-1 shows Oldham's three most important isoseismals, which bound the area of perceptible shaking, the region of significant damage to masonry, and the meizoseismal area. The inset shows the first two corresponding isoseismals for the California earthquake of 1906; on that occasion effects comparable with those in the meizoseismal area of 1897 were observed only close to the San Andreas fault. The greatest linear extent of the 1906 isoseismals is nearly the same as in 1897, but the area included is much narrower. The magnitude of the 1906 earthquake was  $8\frac{1}{4}$ . Seismographs which registered the 1897 earthquake were not of modern type; it is difficult to use their records for deter-

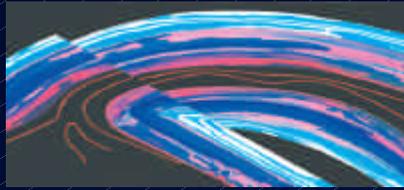
FIGURE 5-2 *Indian earthquake, 1897. Meizo-seismal area. [Oldham.] Solid outline, region of violent shaking; dashed outline, hill area.*



Richter, *Elementary Seismology*, p. 49, quoting Oldham, 1899

Chedrang Fault, ca. **24 Km**, up to **10 m** of vertical displacement in the bedrock

*XVII INQUA Congress*  
*Cairns, July 28th – August 3rd, 2007*  
*Session 60 “Paleoseismology and the ESI 2007 scale”*



[CHAP. 5] SOME GREAT INDIAN EARTHQUAKES

51

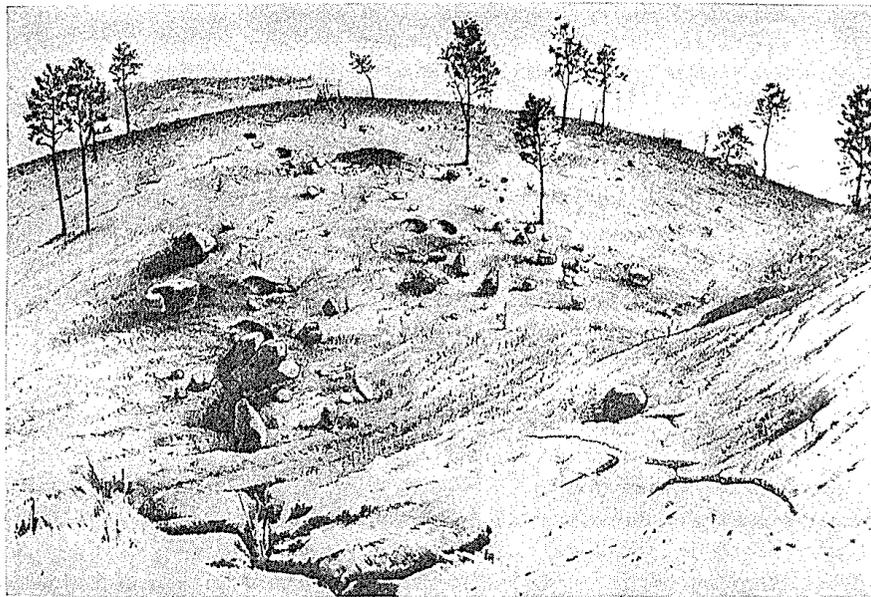


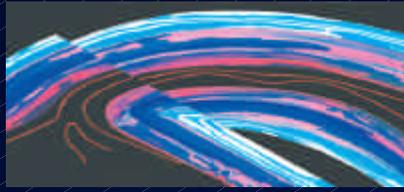
FIGURE 5-4 *Indian earthquake, 1897. Dislodged boulders. [Oldham.]*

his result fully and with circumstantial care. Not merely did eyewitnesses report seeing pebbles bouncing on the ground “like peas on a drumhead,” but numerous instances were observed, photographed, and figured in detail, of posts shot out of their holes and of boulders lifted out of the ground without cutting the edges of their former seats (Fig. 5-4). This high acceleration is consistent with evidence in the granitic rock of the Assam hills, of widespread surface distortion, and of complex fracturing best characterized as shattering. The few features Oldham was able to find in a limited time in difficult jungle country can be no more than a representative fraction of those formed.

#### *Faults and Fractures*

Two true faults were found. The Chedrang fault was the greater, extending over 12 miles with throws up to 35 feet, in crystalline rock. It followed the general line of a stream, which suggests an old line of weakness. However, the winding course of the stream took it back and forth across the fault. Result: a series of waterfalls alternating with pools, as the stream dropped down over the fault scarp or flowed against it. Ponding was also observed along the stream where the former grade had reversed; and in the jungle, out of line with the Chedrang and Samin faults, similar pools indicated extensive warping.

There was other evidence that the surface had been distorted. Oldham’s



*XVII INQUA Congress  
Cairns, July 28th – August 3rd, 2007  
Session 60 “Paleoseismology and the ESI 2007 scale”*

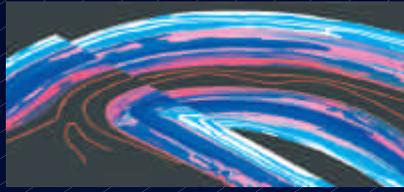


**MM scale, 1931; intensity XII**

Damage total - practically all works of construction damaged greatly or destroyed.

Disturbances in ground great and varied, numerous shearing cracks. Landslides, falls of rock of significant character, slumping of river banks, etc. numerous and extensive. Wrenched loose, tore off, large rock masses.

**Fault slips in firm rock, with notable horizontal and vertical offset displacements.** Water channels, surface and underground, disturbed and modified greatly. Dammed lakes, produced waterfalls, deflected rivers, etc. Waves seen on ground surfaces (actually seen, probably, in some cases). Distorted lines of sight and level. **Threw objects upward into the air.**



*XVII INQUA Congress  
Cairns, July 28th – August 3rd, 2007  
Session 60 “Paleoseismology and the ESI 2007 scale”*



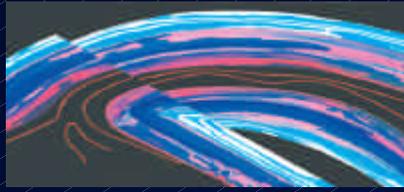
## **MSK scale, 1964; intensity XII**

(a) Practically all structures above and below ground are greatly damaged or destroyed

(c) The surface of the ground is radically changed.

Considerable ground cracks with extensive vertical and horizontal movements are observed. Fall of rock and slumping of river banks over wide areas; lakes are dammed; waterfalls appear; and river are deflected.

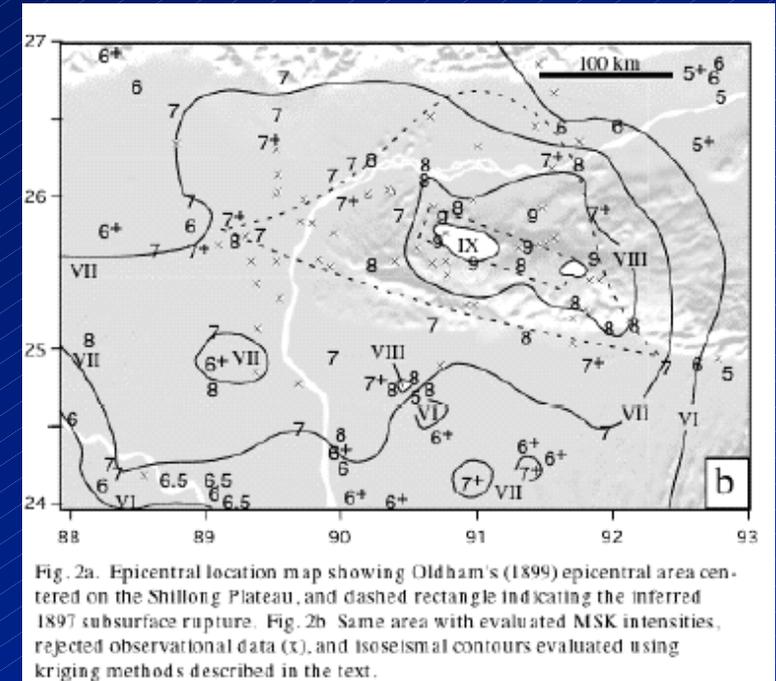
The intensity of the earthquake requires to be investigated in a special way.



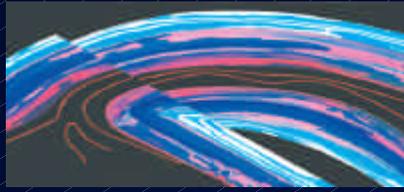
*XVII INQUA Congress  
Cairns, July 28th – August 3rd, 2007  
Session 60 “Paleoseismology and the ESI 2007 scale”*



This cannot be called intensity. This is something else. Intensity, as formally defined by Mercalli, Cancani, Sieberg, Richter, and the other Authors in their original macroseismic scales, must include the comprehensive assessment of earthquake effects based on human perception, damage, AND geological phenomena.



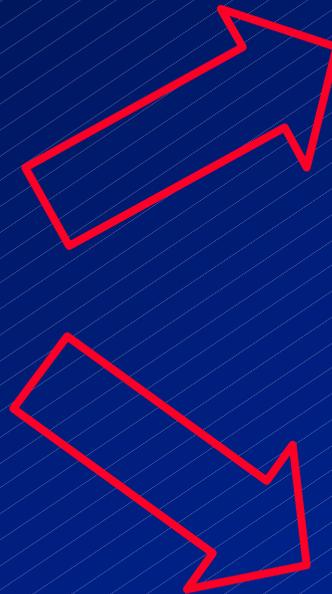
As seismologists, Quaternarists and engineers, we all need this information about intensity, IN THE NEAR FIELD of the strong earthquakes (fault directivity, fault geometry, dynamic source parameters) and IN THE WHOLE FELT AREA (max. ground effect at each site).  
And the ESI scale can be the tool....



*XVII INQUA Congress*  
*Cairns, July 28th – August 3rd, 2007*  
*Session 60 “Paleoseismology and the ESI 2007 scale”*

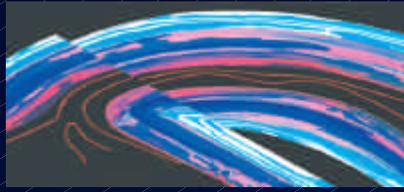


**ESI 2007 scale**



**Better link to dynamic  
source parameters and  
maximum magnitude  
determination**

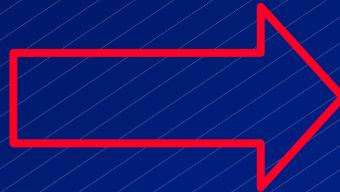
**Tool for the identification  
of most severe ground  
effects at each site**



*XVII INQUA Congress*  
*Cairns, July 28th – August 3rd, 2007*  
*Session 60 “Paleoseismology and the ESI 2007 scale”*



**ESI 2007 scale**



**MOST IMPORTANT**  
**consistent intensity**  
**assessment for both**  
**historical and**  
**instrumental events;**  
**quality of the data and**  
**resolution**

# Vulnerability – Damage – Intensity

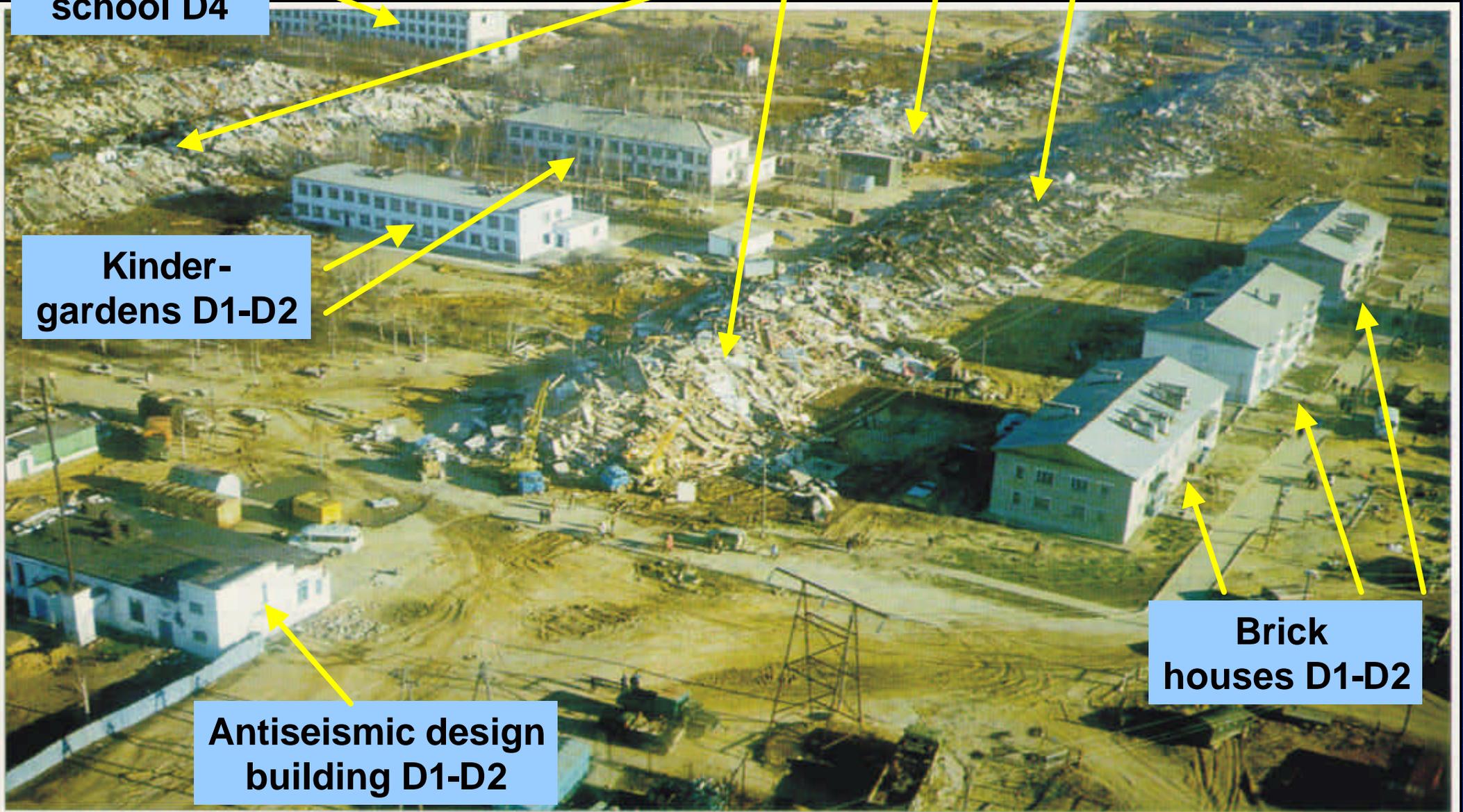
3-store brick school D4

5-store buildings – complete collapse (D5)

Kinder-gardens D1-D2

Brick houses D1-D2

Antiseismic design building D1-D2



# Ruben Tatevossian (2007)

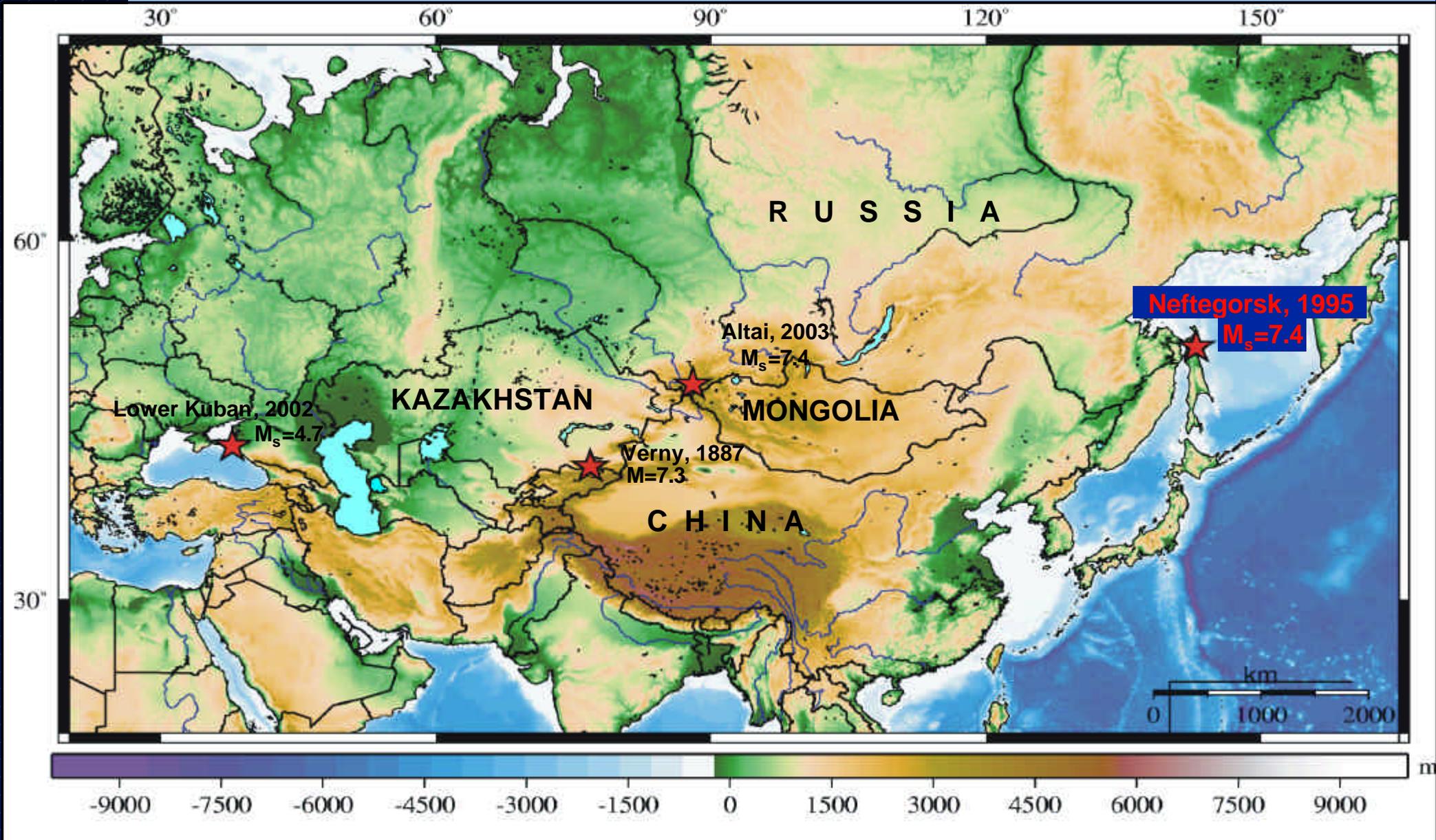
## Earthquake intensity: concept and applications



**Data of the Epicentral Seismological Expedition of the  
Institute of Physics of the Earth, RAS**

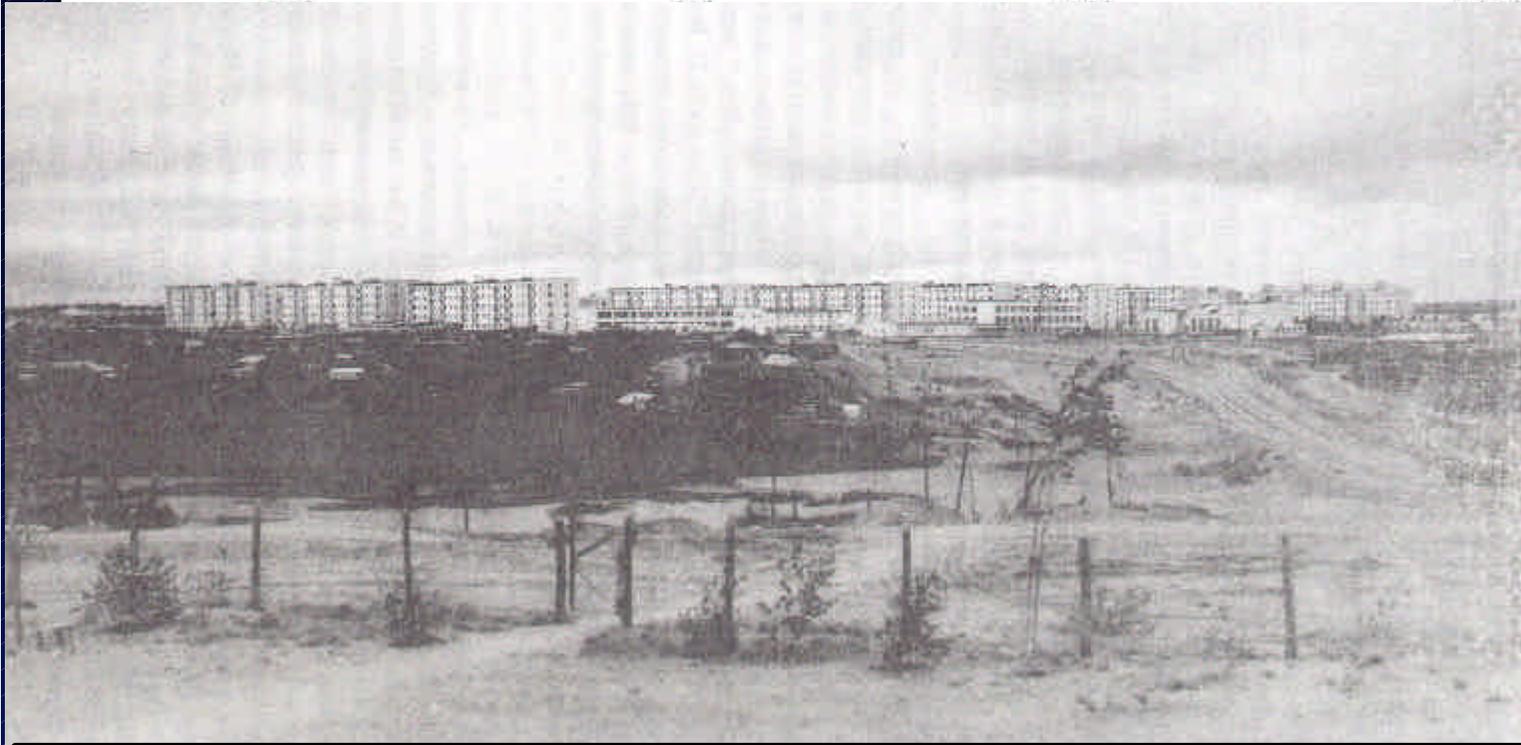
# Case studies

## Application of the INQUA scale to recent earthquake: part 2

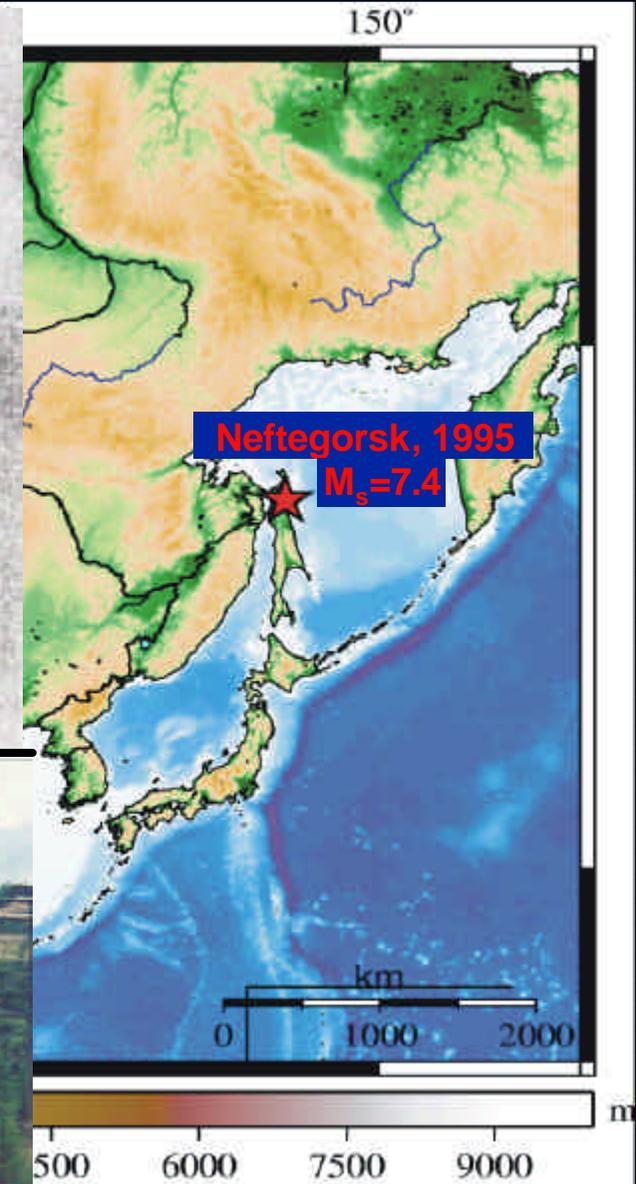


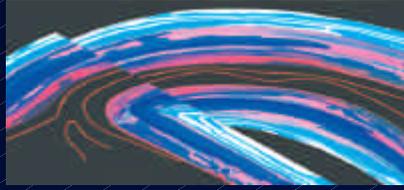
# Case studies

## Application of the INQUA scale to recent earthquake: part 2



(c)





*XVII INQUA Congress*  
*Cairns, July 28th – August 3rd, 2007*  
*Session 60 “Paleoseismology and the ESI 2007 scale”*



### 3. STRUCTURE OF THE ESI 2007 SCALE

Therefore, like any other diagnostic effects used in the scales, environmental ones must be constantly updated, in order to keep the physical phenomena (such as surface faulting, landsliding, and hydrological changes) in line with the damage indicators.

# Definition of intensity degrees

## *Definizione dei gradi di intensità*



From I to III: There are no environmental effects that can be used as diagnostic.

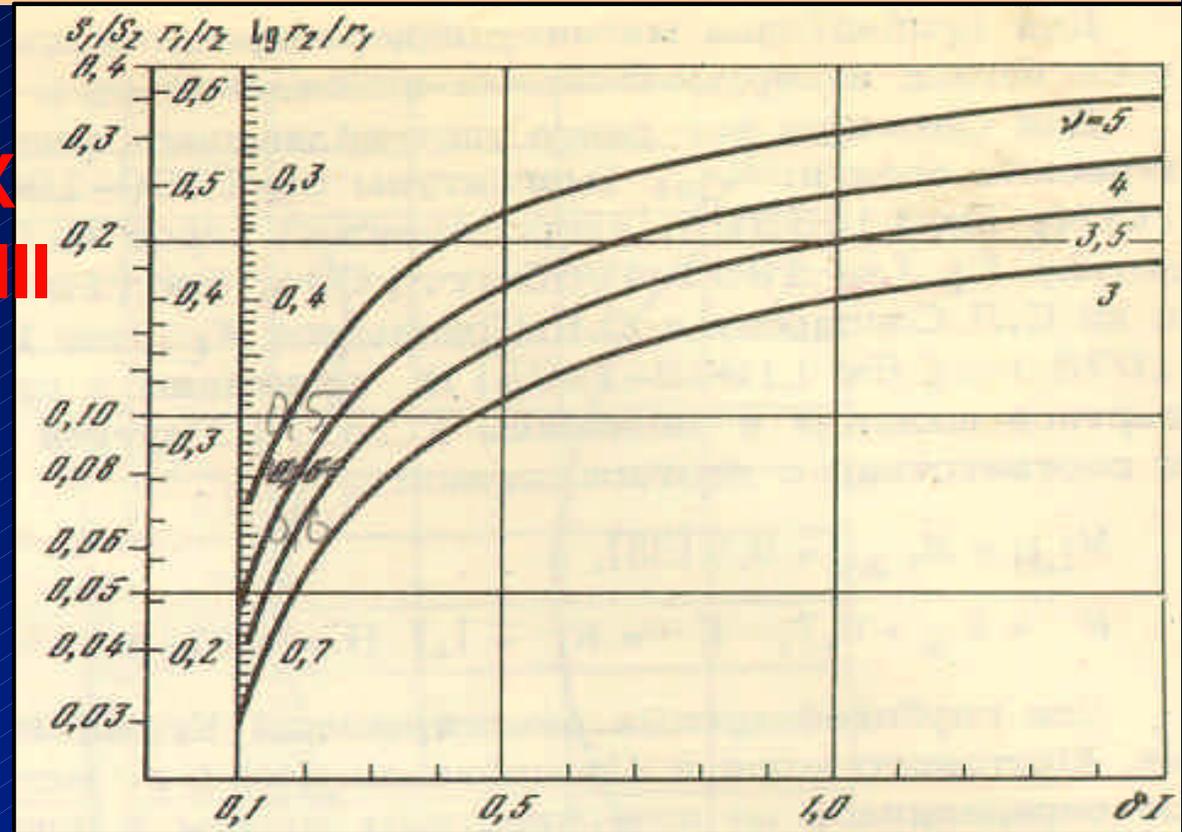
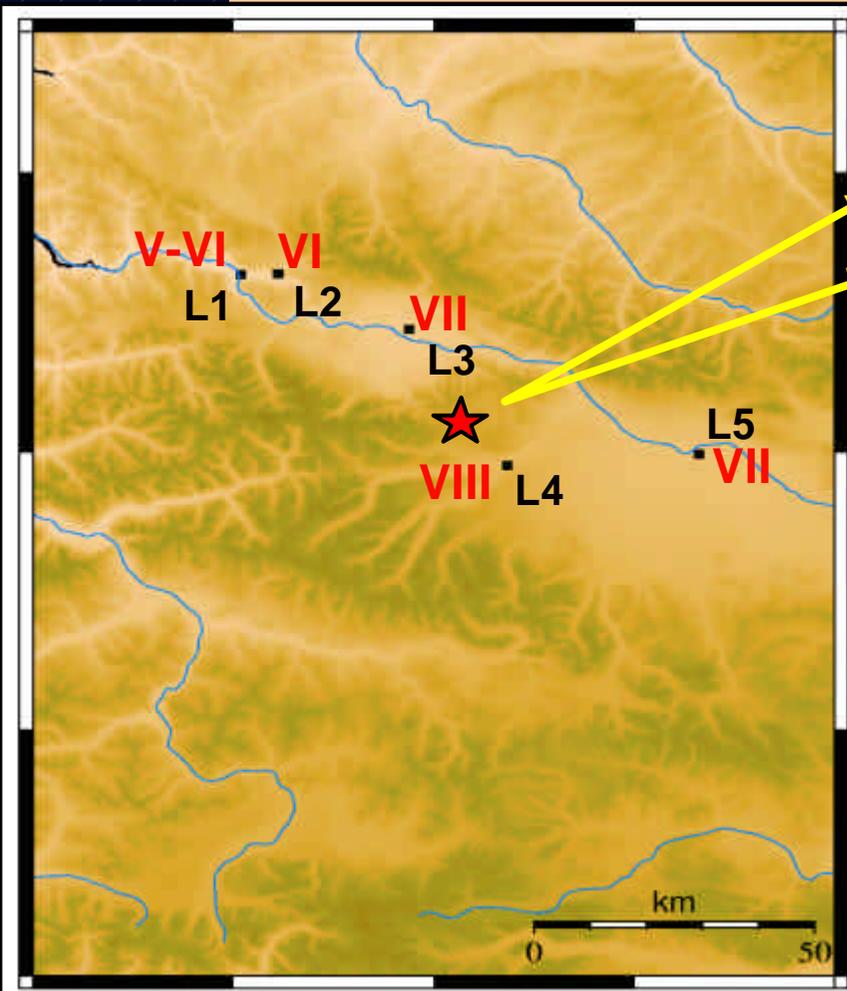
### **IV - LARGELY OBSERVED - First unequivocal effects in the environment**

*Primary effects* are absent.

*Secondary effects:*

- a) Rare small variations of the water level in wells and/or of the flow-rate of springs are locally recorded, as well as extremely rare small variations of chemical-physical properties of water and turbidity in springs and wells, especially within large karstic spring systems, which appear to be most prone to this phenomenon.
- b) In closed basins (lakes, even seas) seiches with height not exceeding a few centimeters may develop, commonly observed only by tidal gauges, exceptionally even by naked eye, typically in the far field of strong earthquakes. Anomalous waves are perceived by all people on small boats, few people on larger boats, most people on the coast. Water in swimming pools swings and may sometimes overflow.
- c) Hair-thin cracks (millimeter-wide) might be occasionally seen where lithology (e.g., loose alluvial deposits, saturated soils) and/or morphology (slopes or ridge crests) are most prone to this phenomenon.
- d) Exceptionally, rocks may fall and small landslide may be (re)activated, along slopes where the equilibrium is already near the limit state, e.g. steep slopes and cuts, with loose and generally saturated soil.
- e) Tree limbs shake feebly.

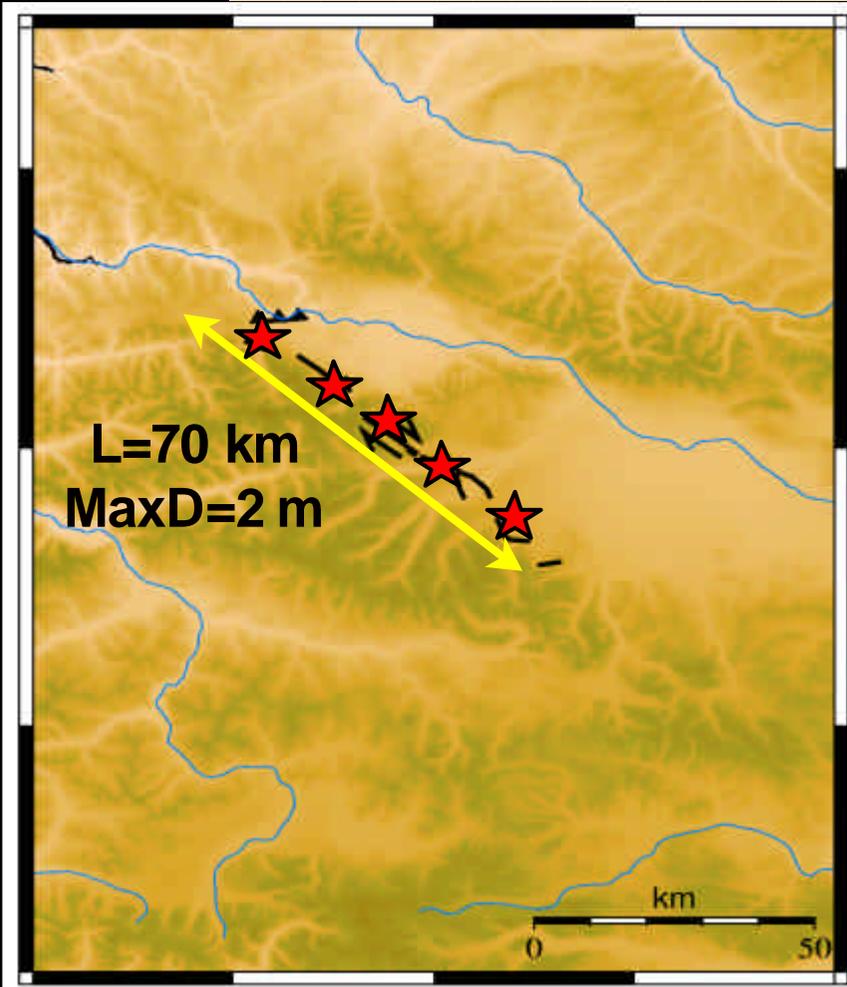
# Macroseismic Epicenter and $I_0$



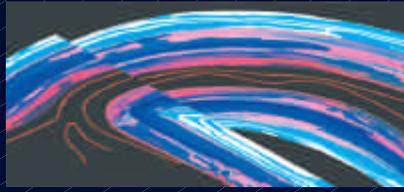
$I_0 = I_1 + dI$ , where  $I_1$  is radius of the first isoseismal, and  $dI$  depends on ratio of first to second isoseismal sizes (scaled for different attenuations  $n$ ).

Epicenter is a point – like any other locality on the map. To assess  $I_0$  we do extrapolation (using nomograms or by expert judgment) from distribution of observed intensities in the localities.

# ESI 2007 Epicenter and $I_0$



**Epicentral intensity is an earthquake characteristic parameter. It is evaluated based on surface rupture (length or max offset). When the source does not expose on the surface – based on total area of secondary effects.**



**XVII INQUA Congress**  
**Cairns, July 28th – August 3rd, 2007**  
**Session 60 “Paleoseismology and the ESI 2007 scale”**

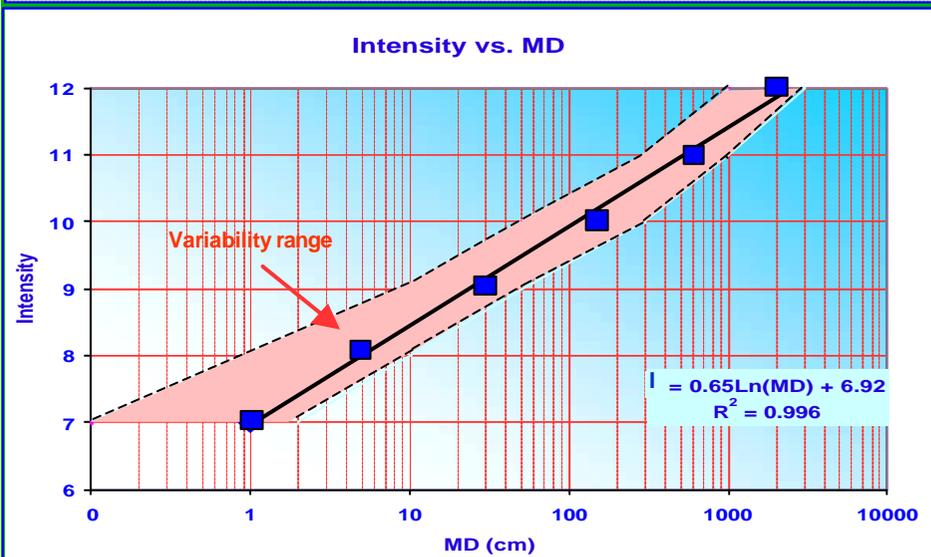
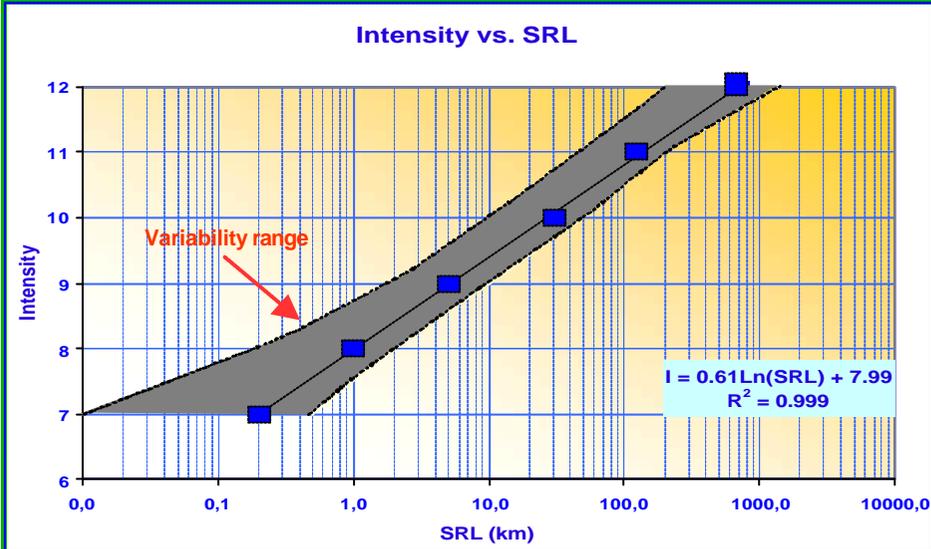


**Tab. 1 - Range of surface faulting parameters (primary effects) and typical extents of total areas (secondary effects) for each intensity degree.**

- Valori di riferimento per ciascun grado di intensità relativo ai parametri di fagliazione superficiale (effetti primari) e all'area totale degli effetti secondari.

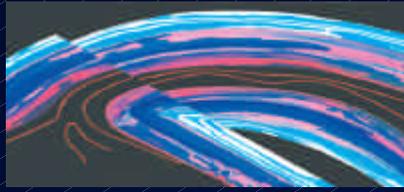
I <sub>0</sub> Intensity	PRIMARY EFFECTS		SECONDARY EFFECTS
	Surface Rupture Extent	Max Surface Displacement / Displacement	Total Area
IV	-	-	-
V	-	-	-
VI	-	-	-
VII	(?)	(?)	10 km <sup>2</sup>
VIII	Several hundreds meters	Centimetric	100 km <sup>2</sup>
IX	10 - 100 km	1 - 40 cm	1000 km <sup>2</sup>
X	10 - 60 km	40 - 200 cm	5000 km <sup>2</sup>
XI	60 - 150 km	200 - 700 cm	10000 km <sup>2</sup>
XII	> 150 km	> 700 cm	> 50000 km <sup>2</sup>

(?) Limited surface fault rupture, tens to hundreds meters long with centimetric offset may occur essentially associated to very shallow earthquakes in volcanic areas.



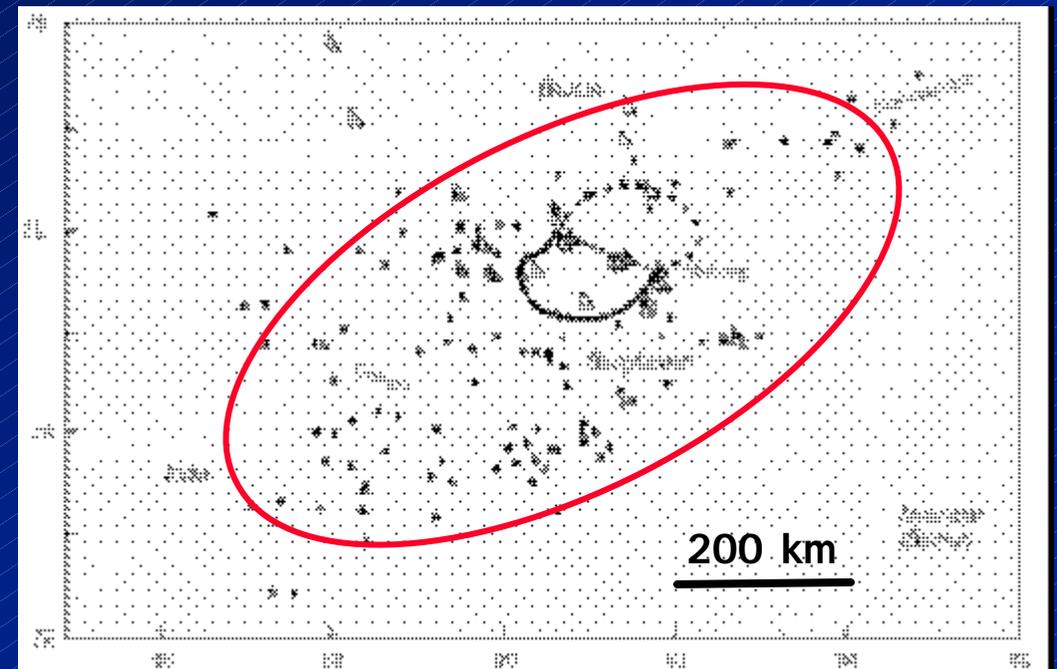
ESI 2007	SRL range	MD range	SRL plot (km)	MD plot (cm)
VII	generally absent or negligible, might be hundreds of meters for very shallow events	generally absent or negligible, centimetric for very shallow events	0.2	1
VIII	generally absent might be up to several hundred meters	up to a few cm, typically less or even absent	1	5
IX	up to a few km	in the order of several cm	5	30
X	few tens of km	from tens of cm up to a few meters	30	150
XI	from several tens up to more than 100 km	several meters	120	600
XII	> few hundreds of km	up to 24 m (largest known displacement)	700	2000

Comerci et al., later today..

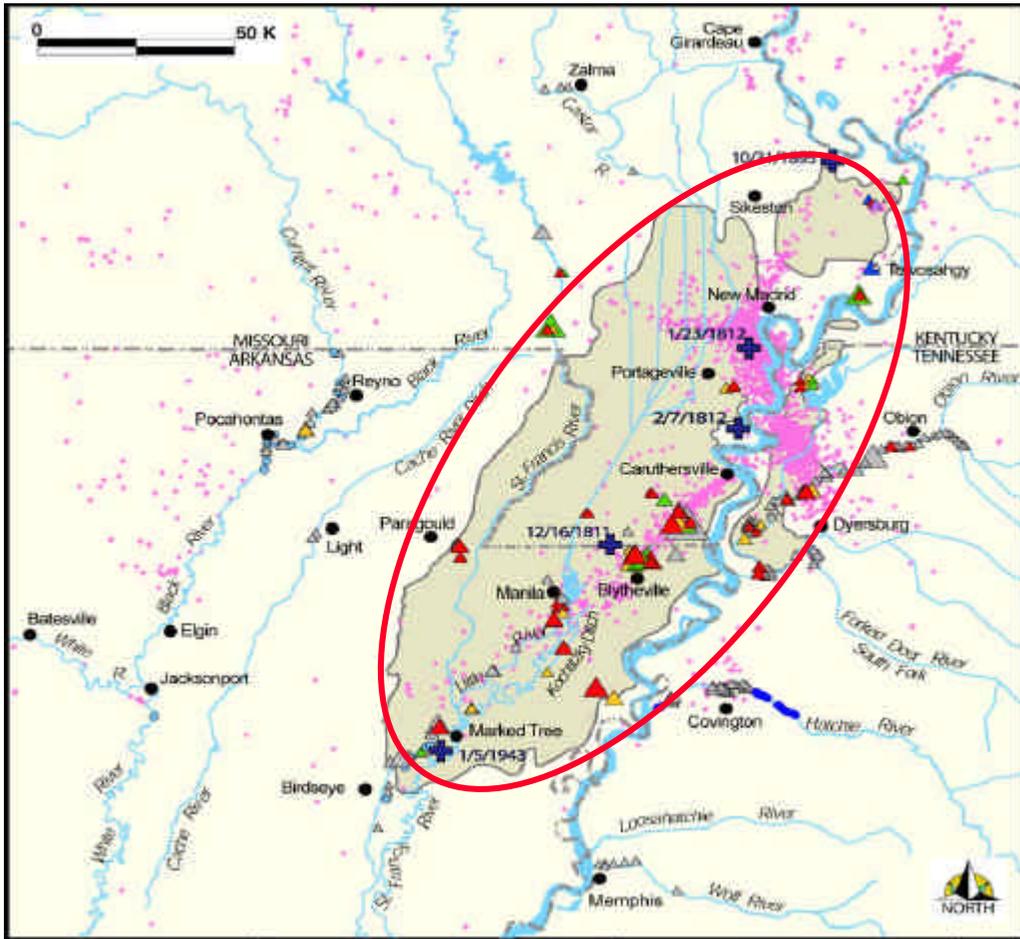


## 4. Total area of liquefaction: Assam, New Madrid and Anchorage

Liquefaction sites (#) and landslide locations (triangles) reported for the 12 June 1897, M8+ Assam earthquake mainshock (as revised by Ambraseys and Bilham (2003))



TOTAL AREA OF LIQUEFACTION ca. 250.000 KM<sup>2</sup>  
| esi = XII |



Environmental effects during the New Madrid 1811-1812, M7.5-8?, seismic sequence - Tuttle and Schweig (2003) NEHRP Report

Best Estimates of Age	Sand Blow Thickness	Dikes (all widths)
▲ A.D. 1811-1812	▲ 0.1-0.49 m	▲ Dikes (all widths)
▲ A.D. 1450+/- 150 yr	▲ 0.5-0.99 m	⊕ Epicenters of historic earthquakes
▲ A.D. 900 +/- 100 yr	▲ 1.0-1.49 m	● Geologic sites
▲ A.D. 300 +/- 200 yr	▲ 1.5-1.99 m	■ Area with >1% of ground surface covered by sand blows
▲ B.C. 2350 +/- 200 yr	▲ 2.0-2.49 m	□ Earthquake epicenters (1974-1991)
▲ Holocene features, age poorly constrained		

TOTAL AREA OF LIQUEFACTION ca. 20.000 KM<sup>2</sup>

I esi = XI

# Geologic effects of earthquake of 27 March 1964 (a XII on the ESI 2007 scale)

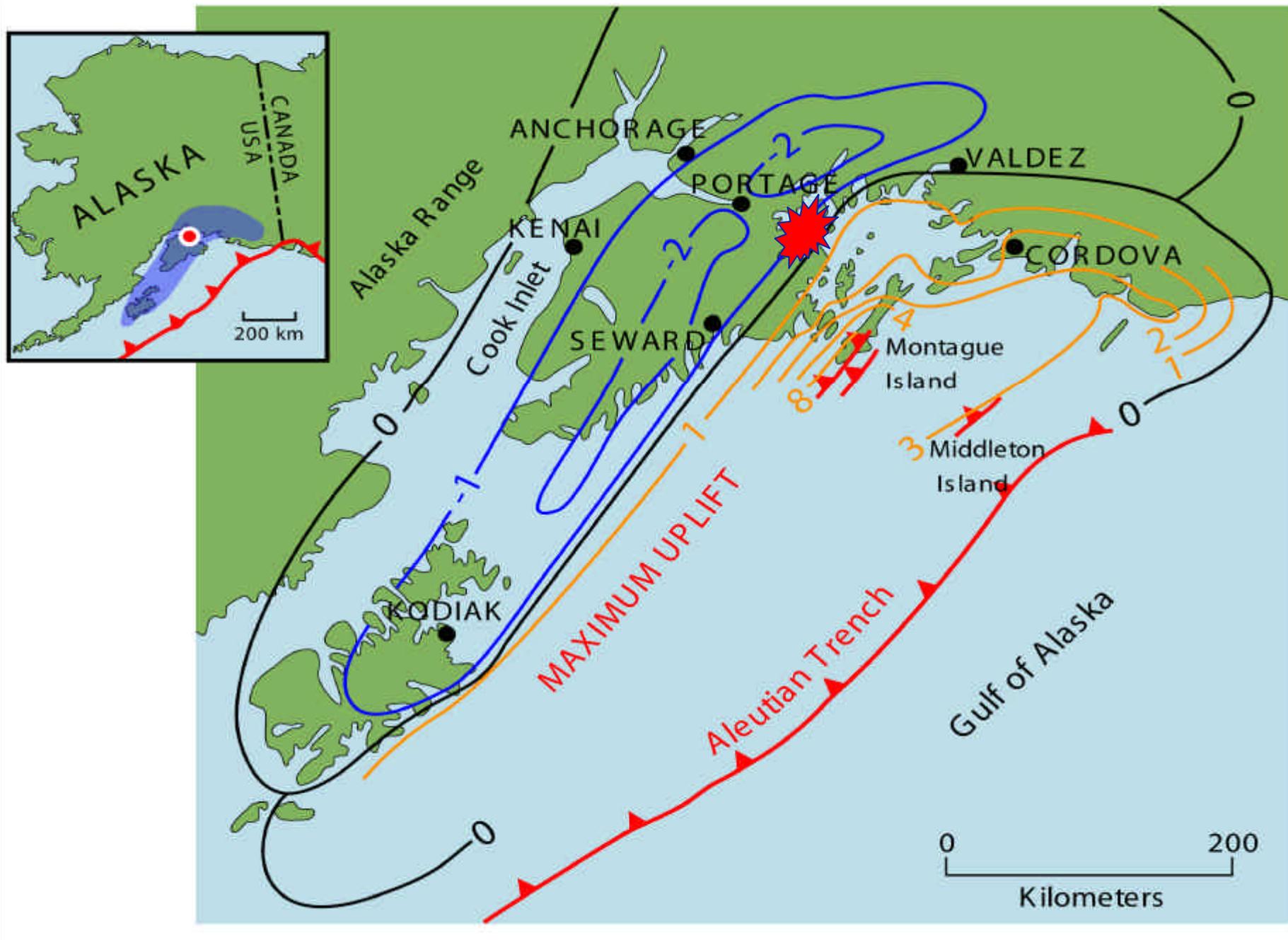
- regional coastal uplift – area of 60,000 km<sup>2</sup> uplifted 1-2 m; along fault 850 km long
- regional coastal subsidence – area of 110,000 km<sup>2</sup> subsided up to 3 m
- surface faulting and localized uplift – max 3-9 m
- liquefaction and lateral spreading – >800,000 km<sup>2</sup>
- landsliding – 250,000 km<sup>2</sup>
- local tsunamis – landslide-induced near-field tsunamis



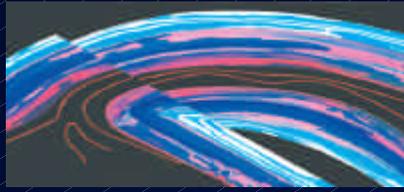
# Earthquakes accompanied by tsunamis: Their paleoseismic records and application to the INQUA intensity scale

Alan Nelson  
U.S. Geological Survey  
Golden, Colorado





**Alaska, M9, Earthquake of 27 March 1964**



*XVII INQUA Congress*  
*Cairns, July 28th – August 3rd, 2007*  
*Session 60 “Paleoseismology and the ESI 2007 scale”*



## 5. WHY THE ESI 2007 SCALE IS RELEVANT FOR PALEOSEISMOLOGY??

### AND WHY IS THIS A FIELD OF INTEREST FOR QUATERNARISTS??

Paleo-perspective of earthquakes

In this perspective, the study of EEE aims at linking seismological and paleoseismological records



Cracks in saturated soil and/or loose alluvium up to 1 cm:	MSK: VI
a few cm:	MSK: VIII; MM: VIII; MCS: VIII
up to 10 cm:	MSK: IX; MM: IX
a few dm up to one meter:	MSK: X; MCS: X
Cracks on road backfills and on natural terrigenous slopes over 10 cm	MSK: VII, VIII, IX; MM: VIII; MCS: VIII
Cracks on dry ground or on asphalted roads	MSK: VII, IX, XI; MCS: X, XI; JAP: VI
Faults cutting poorly consolidated Quaternary sediments	MSK: XI; MCS: XI
Faults cutting bedrock at the surface	MSK: XII; JAP: VII
Liquefaction and/or mud volcanoes and/or subsidence	MSK: IX, X; MM: IX, X; MCS: X, XI
Landslides in sand or gravel artificial dykes	MSK: VII, VIII, X; MM: VII; MCS: VII
Landslides in natural terrigenous slopes	MSK: VI, IX, X, XI; MM: X; MCS: X, XI; JAP: VI, VII
Rockfalls	MSK: IX, XI, XII; MM: XII; MCS: X, XI
Turbulence in the closed water bodies and formation of waves	MSK: VII, VIII, IX; MM: VII; MCS: VII, VIII
Formation of new water bodies	MSK: VIII, X, XII; MCS: XII
Change in the direction of flow in watercourses	MSK: XII; MCS: XII
Flooding	MSK: X, XII; MM: X; MCS: X
Variation in the water level of wells and/or the flow rate of springs	MSK: V, VI, VII, VIII, IX, X; MM: VIII; MCS: VII, X
Springs which dry out or are starting to flow	MSK: VII, VIII, IX

## Paleoseismology and macroseismic intensity

Environmental effects in the MCS-1930, MM-1931, MSK-1964 and Japanese (JAP - Omori scale) intensity scales

**1. Effects of the earthquakes on the natural environment are essentially effects on Quaternary deposits and landforms.**

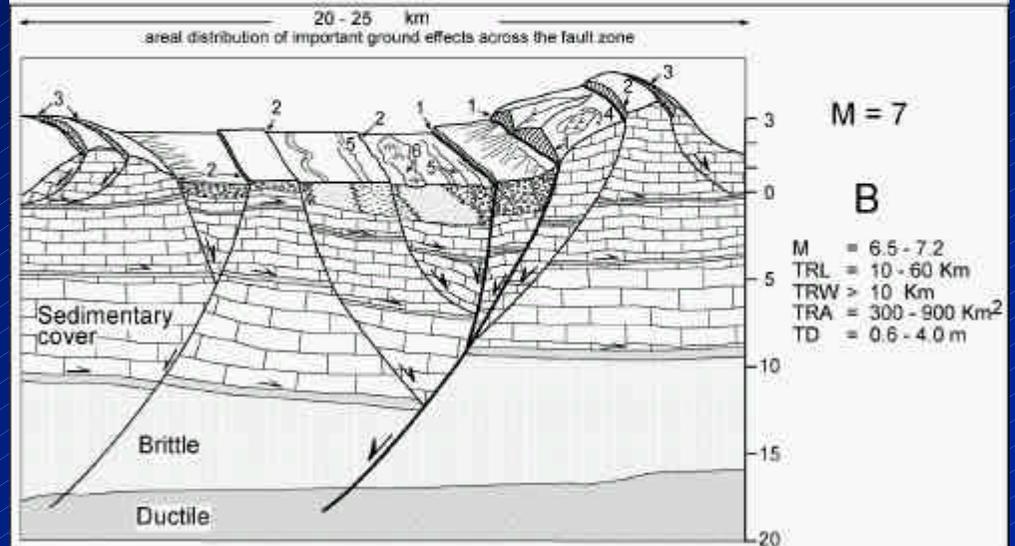
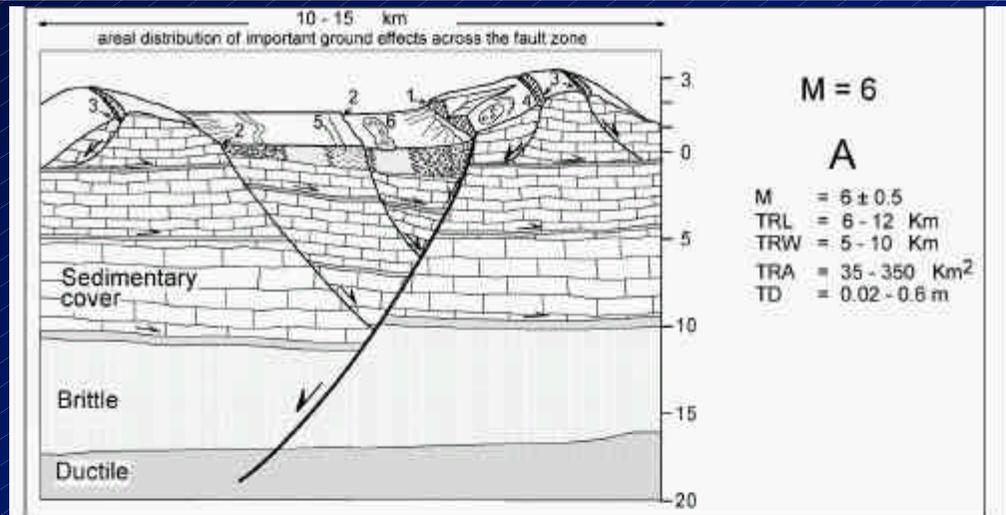
**2. A classification of these effects allows to understand the role played by earthquake processes in the Quaternary evolution of a region**

**2. Only through this understanding it is possible to properly assess the seismic hazard = the definition of the Seismic Landscape of a region**

Epicentral  
intensity IX MCS  
Sept 26, 1997  
Colfiorito eq.

## Seismic Landscapes of the Apennines

Epicentral  
intensity X MCS  
Nov 23, 1980  
I rpinia eq



Seismo-tectonic landforms (i.e. fault scarps and triangular facets with a scarp at the base) related to:

1 - primary surface ruptures

2 - secondary and sympathetic surface ruptures

Seismo-gravitational landforms:

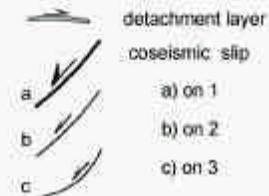
3 - deep-seated gravitational deformation

4 - landslide

Others seismic induced landforms:

5 - ground failure

6 - liquefaction



M = magnitude

TRL = typical rupture length

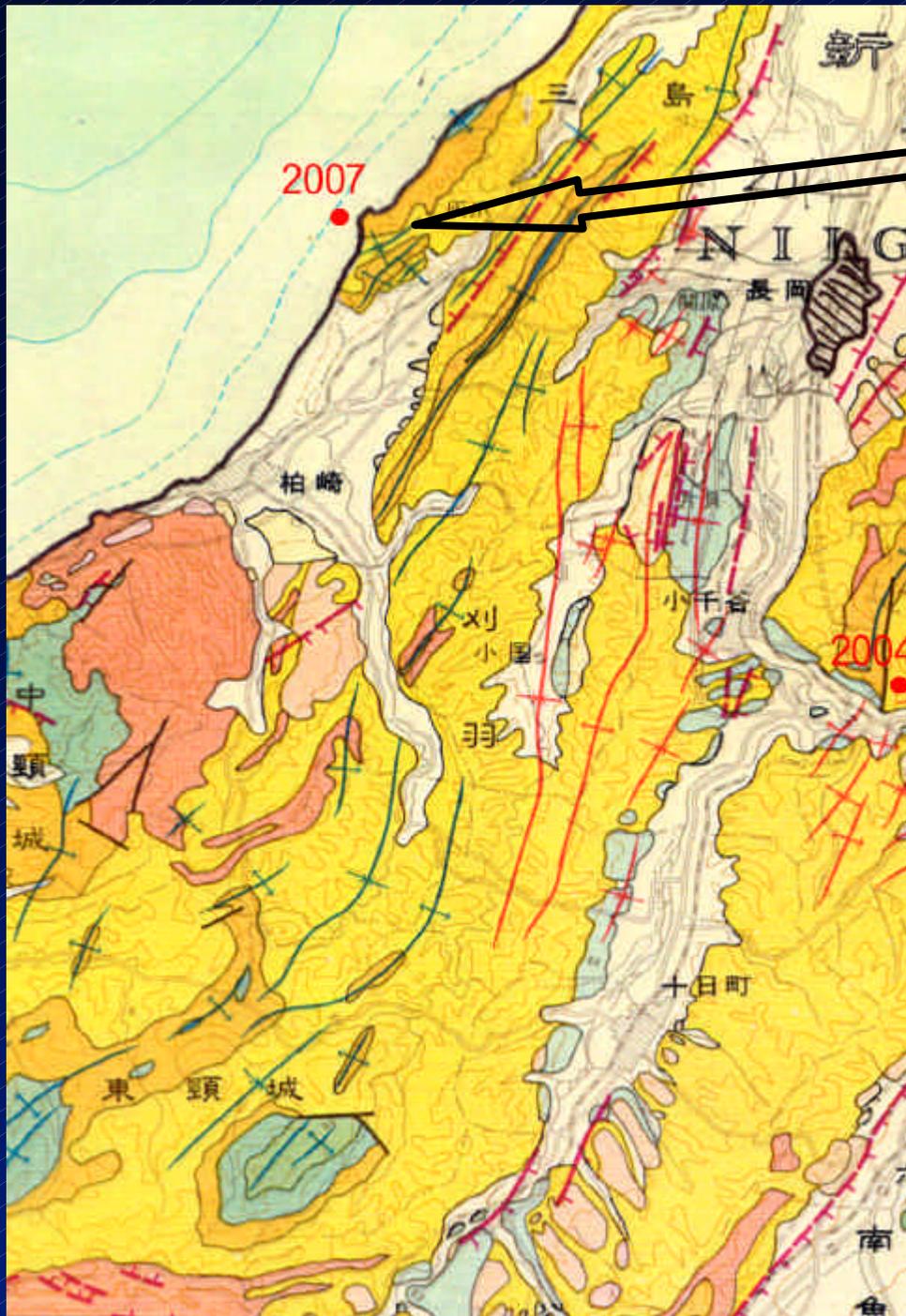
TRW = typical rupture width

TRA = typical rupture area

TD = typical displacement

INT = epicentral macroseismic intensity

✓Kashiwakaki-Kariwa NPP site



6. Chuetsu-Oki  
Earthquake  
of 2007.July, 16,  
Magnitude,6.8

1964

2004

2007

*Yoko Ota and Takashi Azuma*

# Coseismic coastal uplift



# Surface cracks



# Landslides



Previous

Back to Search Results Page

Next >



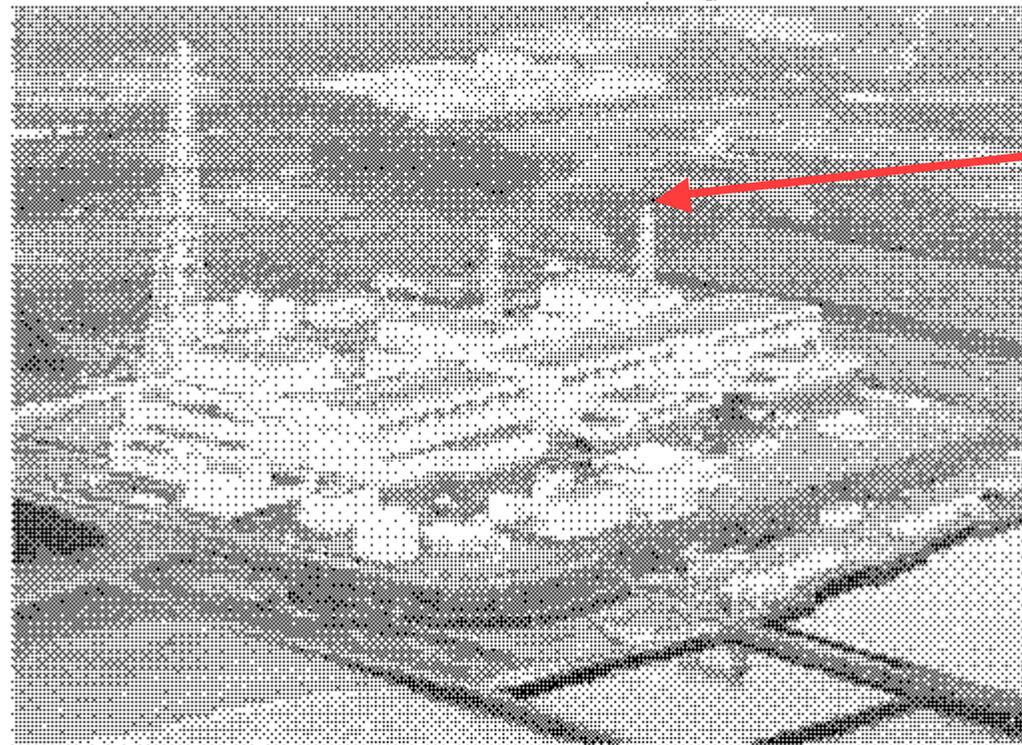
Vehicles drive on a damaged road leading to the Tokyo Electric Power Co.'s Kashiwazaki-Kariva nuclear power plant (R-background) in Kariva village, Kashiwazaki, 18 July 2007. Authorities in Japan on 17 July were investigating a second nuclear scare following a deadly earthquake, as relief workers struggled to feed and shelter thousands of shaken survivors. About 100 sealed barrels filled with contaminated clothes and gloves tipped over at the massive Kashiwazaki-Kariva nuclear power plant in the 16 July 6.9-magnitude quake, which killed nine people and injured more than 1,000 more. AFP PHOTO/KAZUHIRO NOGI (Photo credit should read KAZUHIRO NOGI/AFR/Getty Images)

## Current Picture

Previous

Back to Search Results Page

Next >



Kashiwazaki-Kariva nuclear plant in Kashiwazaki, Niigata Prefecture (State) is seen from helicopter Tuesday, July 17, 2007. The power plant suffered burst pipes, water leaks and radioactive waste spillage when it was hit by Monday's earthquake, the plant's operator announced Tuesday. (AP Photo/Kyodo News) \*\* JAPAN OUT NO SALES MANDATORY CREDIT \*\*

effects, ESI 2007 scale,  
FIG OF CRITICAL



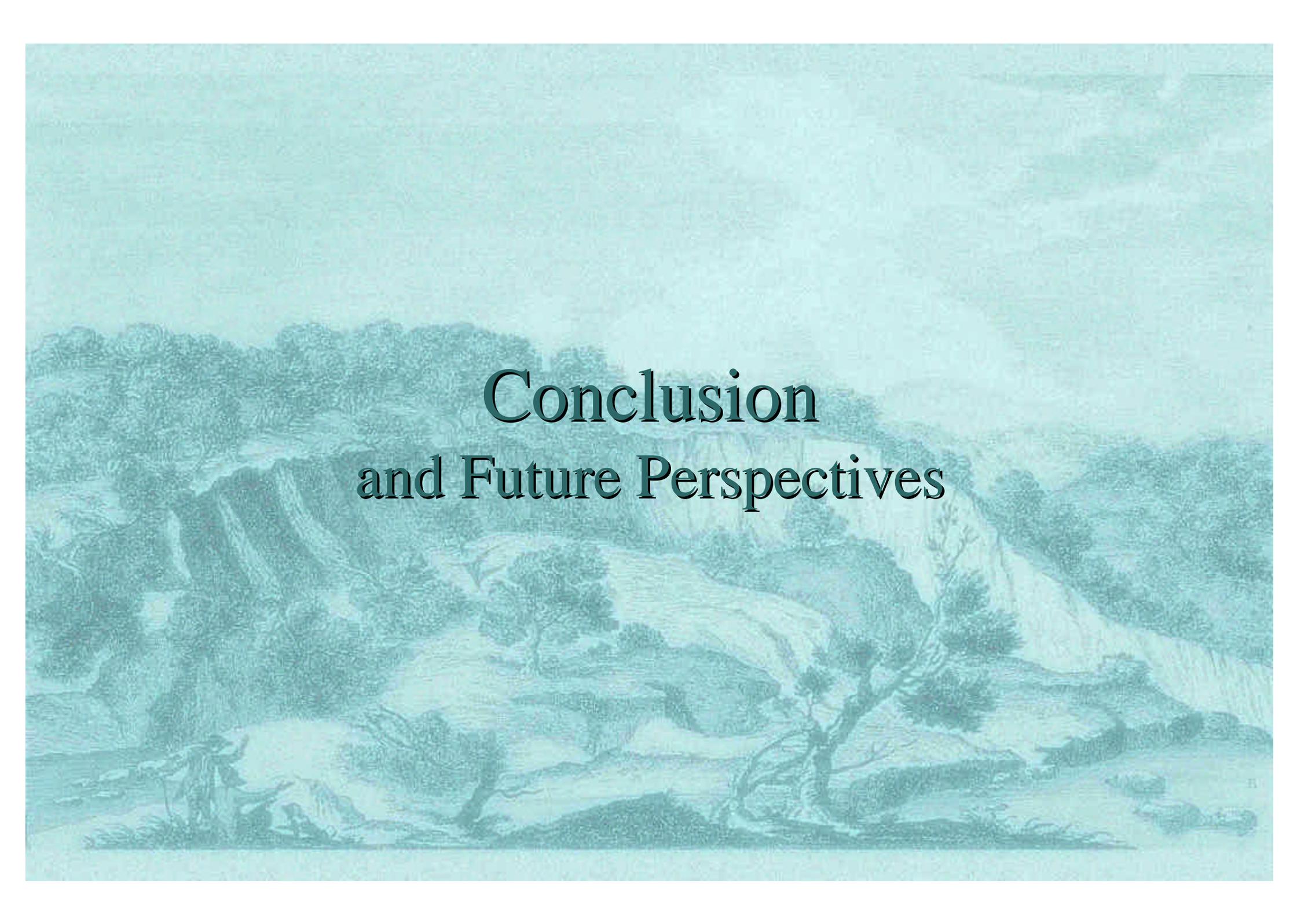


7 scale,  
L

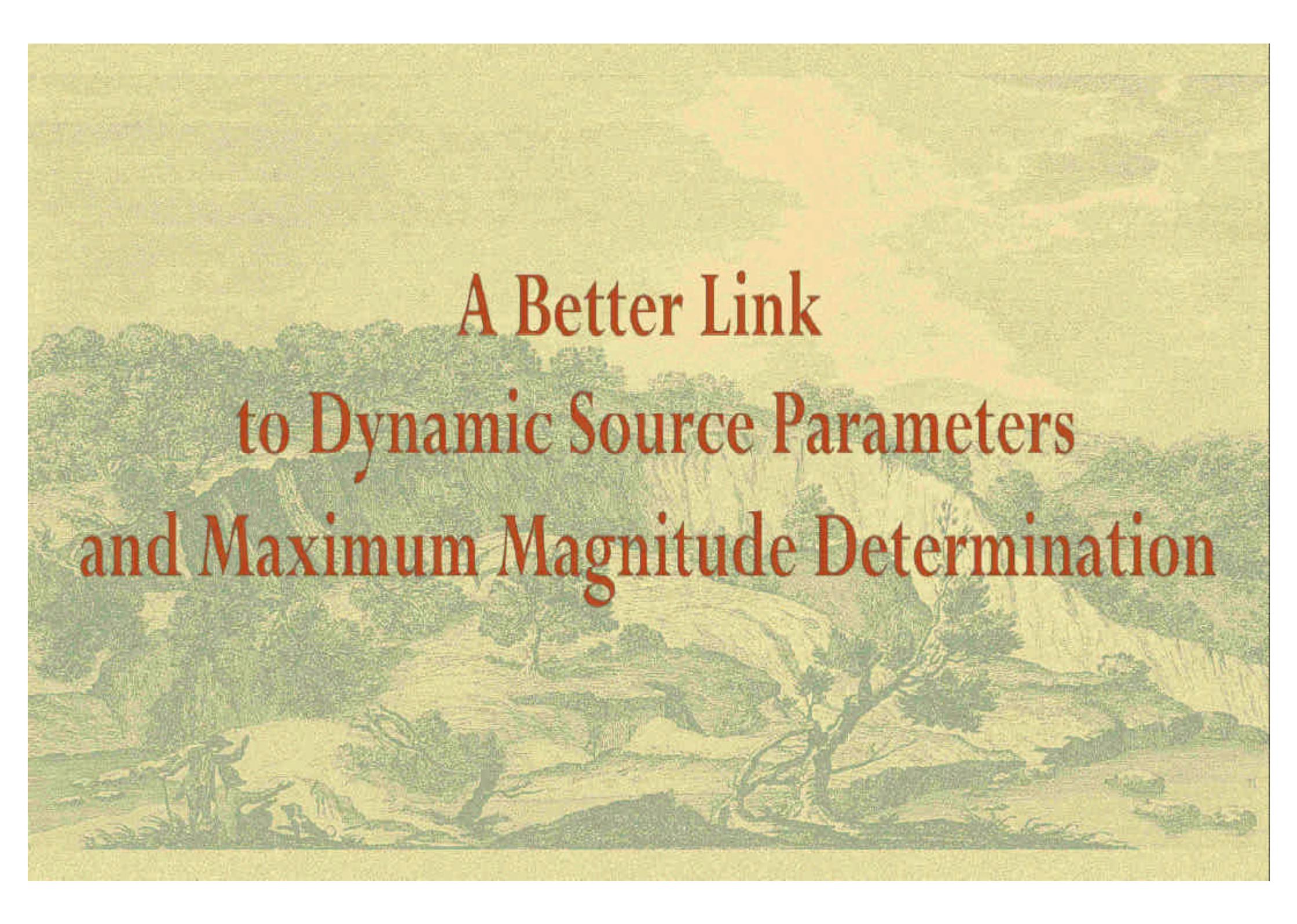


# Identification of maximum ground effect at the site

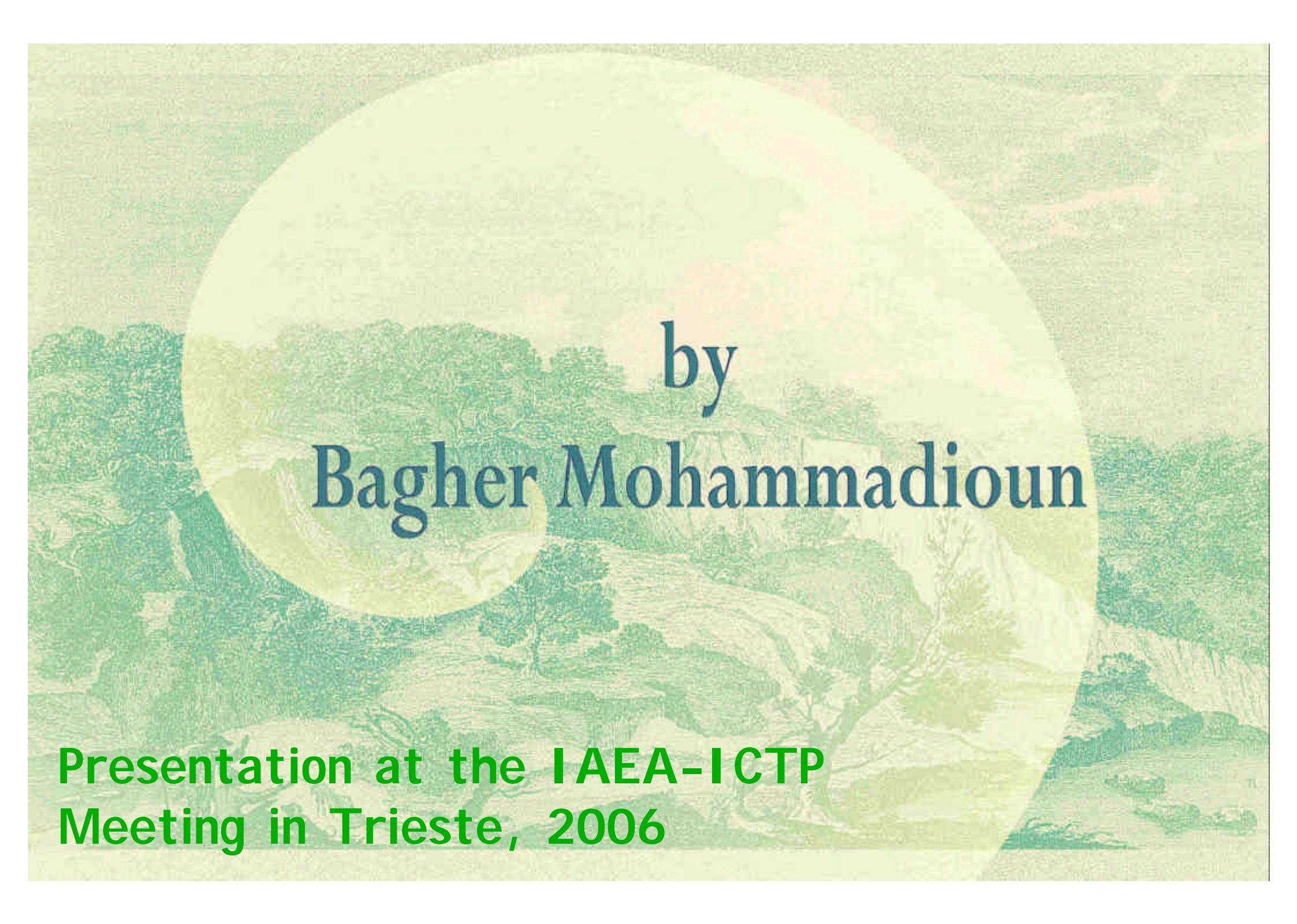


The background is a monochromatic, teal-toned landscape painting. It depicts a mountainous region with a river or stream flowing through a valley. The foreground shows a rocky bank with a few trees and a small structure. The middle ground features a winding path or road through the hills. The background shows more distant, hazy mountains under a light sky. The overall style is that of a classical landscape painting, possibly a reproduction of a work by a 19th-century artist.

# Conclusion and Future Perspectives



**A Better Link  
to Dynamic Source Parameters  
and Maximum Magnitude Determination**



by  
**Bagher Mohammadioun**

**Presentation at the IAEA-ICTP  
Meeting in Trieste, 2006**

1. Today, certain regions including the western United States, Japan, and parts of Eastern Europe benefit from dense instrumental arrays, and seismic risk analysis there makes wide use of the data obtained. Elsewhere, however, including some seismically active countries like China and Turkey, such data is not available, and the input for risk assessment is **primarily historical data**. In this case, the size of events is expressed in terms of macroseismic intensity, and a number of versions of such scales have been in current use during the 20th century (MMI, MSK and JMA, among others).

2. The first step in anti-seismic protection and in determining design parameters is seismic hazard assessment, whether the approach used is deterministic or a probabilistic. This assessment must draw upon a database covering geology and seismology containing parameters that are as complete and uniform as possible, and for which uncertainties have been estimated insofar as possible.

3. While for some quite seismically active regions the collected data permits hazard assessment for conventional buildings, the instrumental observation period **is never long enough to establish hazard level for critical structures**, where low probabilities are involved corresponding to extremely rare events. Instrumental databases must accordingly be supplemented with events described in historical record going back as far as possible in time and, beyond those, with information provided by archeoseismicity, with the analysis of archeological remains, and by paleoseismicity, with the analysis of geological formations, notably by trenching.

4. Historical earthquakes in addition to those not recorded by seismic monitoring arrays are characterized solely by their macroseismic intensity. For earthquake engineering purposes, a bridge must be built between these intensities and the physical parameters used in earthquake-resistant design.

The development, in certain active zones, of accelerograph arrays has allowed strong-motion records to be collected, and from these attenuation models have been built in which magnitude is a key parameter.

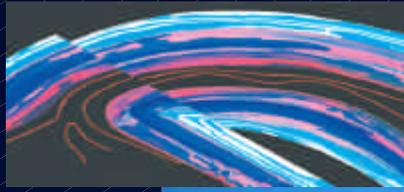
5. In the epicentral zone, these data also make it possible to study the relationships that may exist between magnitude and certain geological effects, notably the rupture length and displacement caused by the earthquake. An examination of intensity scales in current use, notably MMI, reveals that for large intensities in the near field, the progression of the degree of intensity correlates poorly with the observed geological effects.

Unlike these scales, the ESI scale, which is based exclusively on geological effects, does by definition reflect this progression.

6. The classical intensity scales rely strongly on structural responses in the epicentral zone, and these responses remain variable from one region, and one culture, to another, despite efforts to take this into account in recently revised scales. The ESI scale is not subject to this weakness, and further, can be applied in largely unpopulated regions, when the ground surface bears witness to the earthquake's severity.

7. In the context of the Sub-Commission on the INQUA Intensity Scale, a dedicated database is being built. This base will include all the available source parameters including magnitude, rupture length (surface and/or subsurface) displacement (surface and/or mean slip on the fault), together with intensities estimated according to a classical scale.

8. INQUA intensities will be determined from geological effects for contemporary earthquakes as an on-going process. Because this database has achieved statistically significant size, estimates of INQUA intensity will also be able to be made even for historical earthquakes having sparse geological information, by using a correlation between INQUA and MMI intensities calculated from the base.



*XVII INQUA Congress*  
*Cairns, July 28th – August 3rd, 2007*  
*Session 60 “Paleoseismology and the ESI 2007 scale”*



✓ **THANK YOU!!!!**

