2nd INQUA-IGCP-567 International Workshop on Active Tectonics,
Earthquake Geology, Archaeology and Engineering, Corinth, Greece (2011)

EEE Catalogue

The ESI 2007 intensity scale and the EEE Catalogue

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and the INQUA #0811 Working Group

Summary

✓ INQUA TERPRO Subcommission on Paleseismicity projects (since 2003)

✓ Earthquake Environmental Effects (EEEs) and their use for intensity assessment through the ESI scale.

✓The EEE Catalogue: a tool to compare modern, historical and paleoearthquake

✓ Some examples

INQUA TERPRO Subcommission on Paleseismicity projects

- 2003 XVI INQUA Congress, Reno, USA

An independent assessment of earthquake intensity scale based on ground effects: the INQUA Scale (project #0418).

- 2007 XVII INQUA Congress, Cairns, Australia

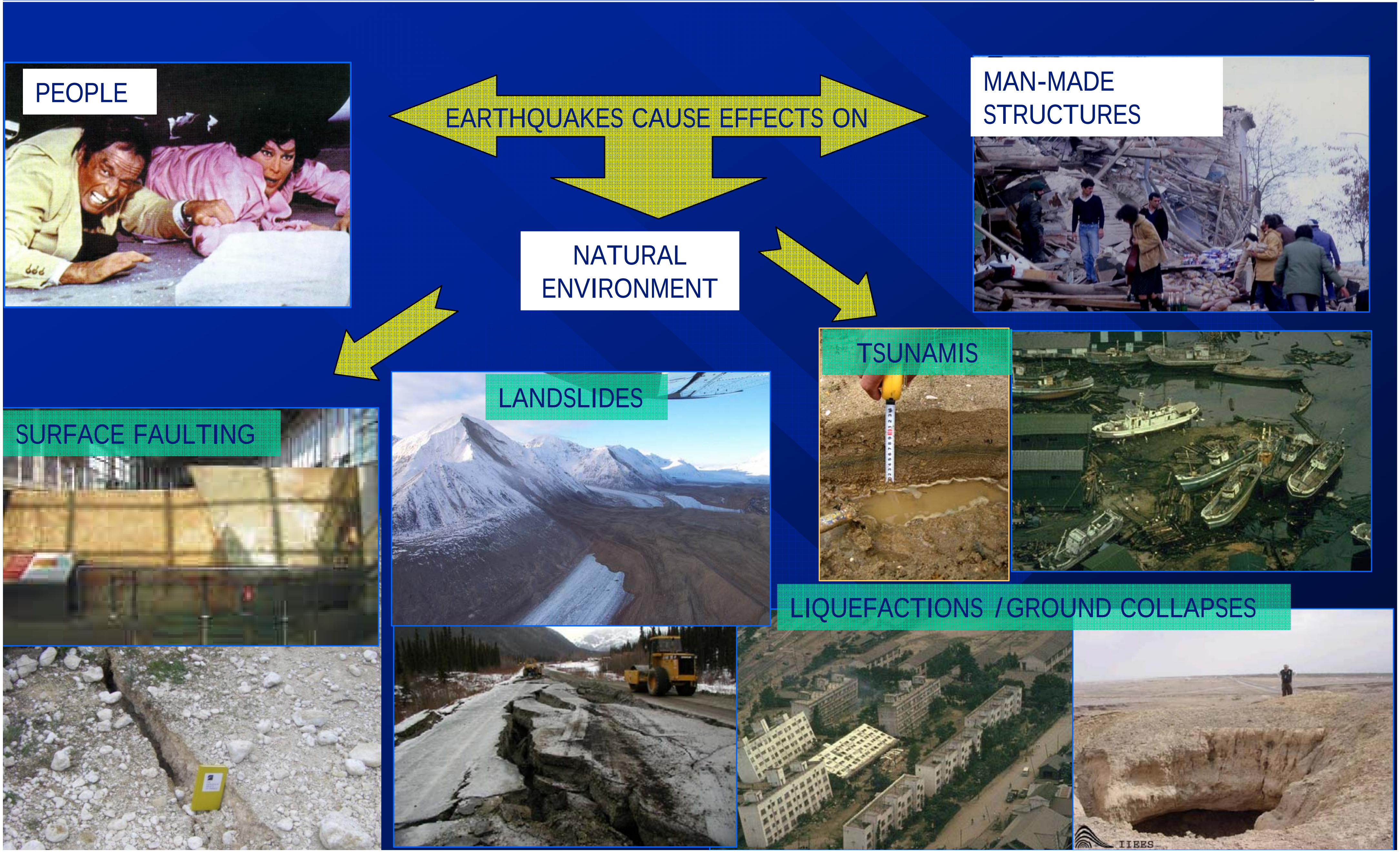
A global catalogue and mapping of Earthquake Environmental Effects (project #0811)

EEE Catalogue

- 2011 XVIII INQUA Congress, Berna, Switzerland

TO BE DECIDED

- 2015 XIX INQUA Congress, Nagoya, Japan


EARTHQUAKES CAUSE EFFECTS ON
PEOPLE
MAN-MADE STRUCTURES
NATURAL ENVIRONMENT
SURFACE FAULTING
LANDSLIDES
TSUNAMIS
LIQUEFACTIONS / GROUND COLLAPSES

Earthquake Environmental Effects

Earthquake Environmental Effects (EEEs) are any phenomena generated by a seismic event in the natural environment. They can be categorized in two main types:

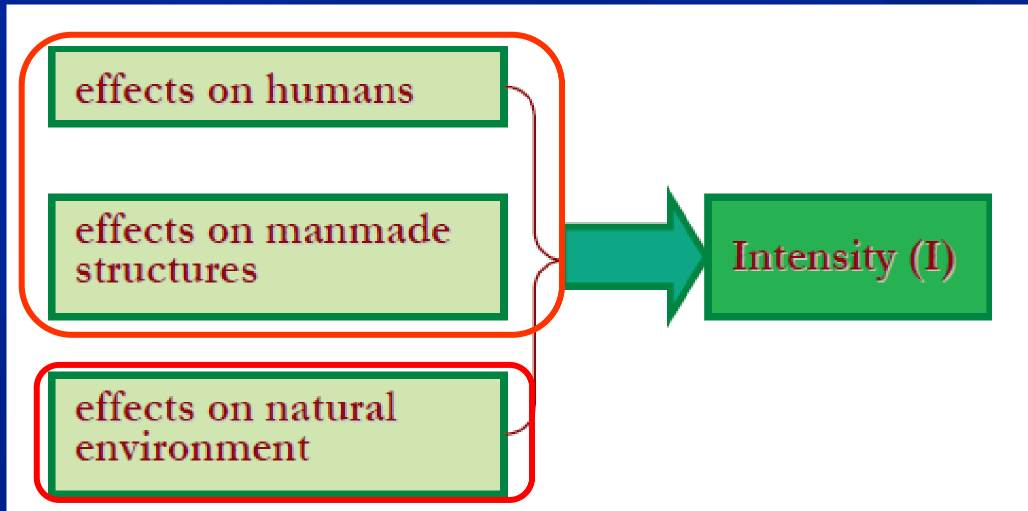
- ✓ *Primary effects*: the surface expression of the capable tectonic source, including surface faulting, surface uplift and subsidence.
- ✓ *Secondary effects*: phenomena generally induced by the ground shaking. They are conveniently classified into eight main categories: slope movements, ground settlements, ground cracks, hydrological anomalies, anomalous waves (including tsunamis), other effects (tree shaking, dust clouds, jumping stones).

The ESI 2007 intensity scale (or INQUA scale)

- ✓ A new intensity scale based only on the characteristics, size and distribution of environmental effects (Michetti et al., 2007).

- ✓ The scale was elaborated and tested in the frame of the 2003 – 2007 INQUA TERPRO SubCommission on Paleoseismicity project "An innovative approach for assessing earthquake intensities: the INQUA Scale, based on seismically-induced ground effects in the environment" (ref. INQUA 0418).

Why a new intensity scale?



Earlier intensity scales (De Rossi, Mercalli, Cancani, Omori, Sieberg) were considering effects on natural environment as a diagnostic elements.

In the second half of the XX century these effects have been progresively disregarded and increasing attention has been paid to the effects on humans and man made structures (MSK and EMS98).

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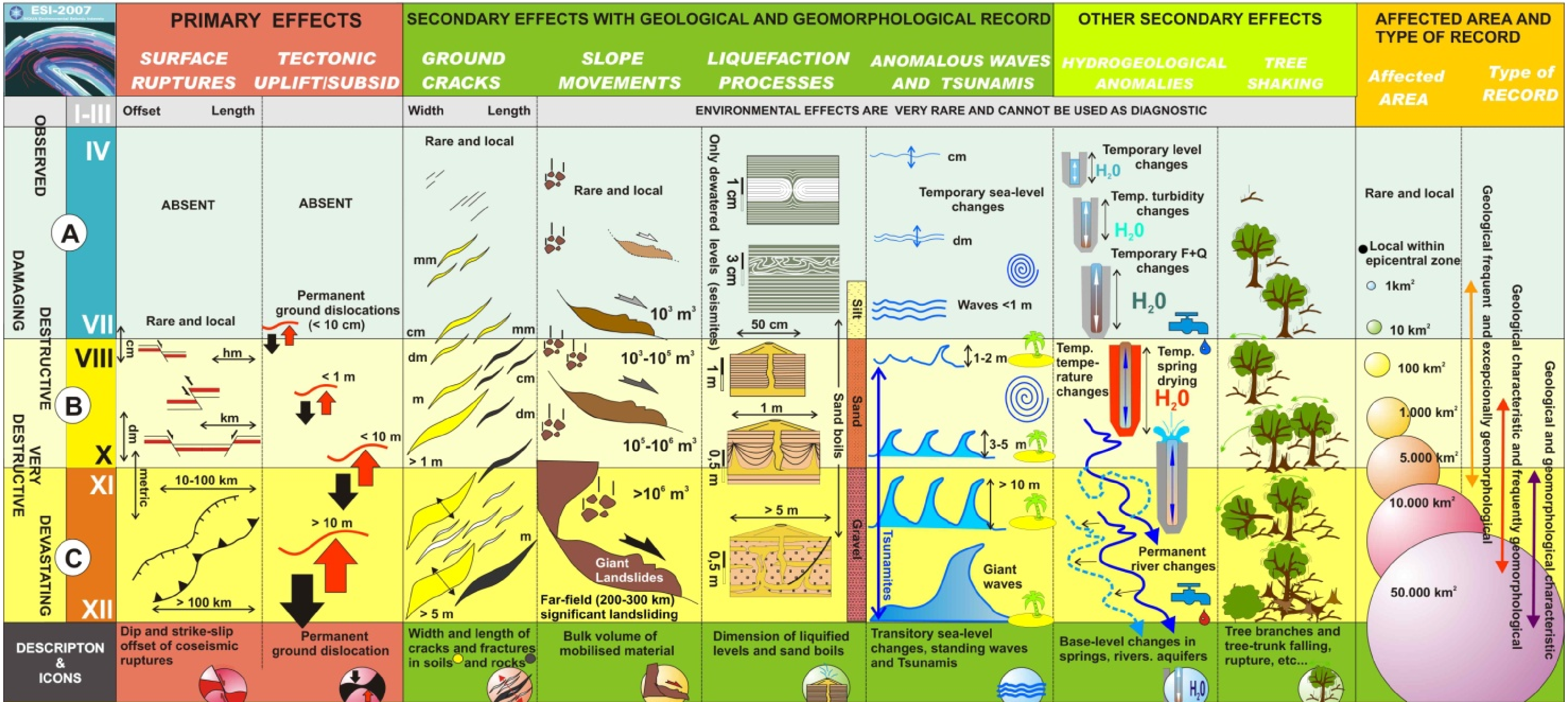
Structure of the ESI 2007 intensity scale

CHART OF THE INQUA ENVIRONMENTAL SEISMIC INTENSITY SCALE 2007 - ESI 07 (Modified from Silva et al., 2008 and Reicherter ett al, 2009)



KEY REFERENCES

Michetti et al., 2007. Environmental Seismic Intensity scale - ESI 2007.Memorie Descrittive della Carta Geologica d'Italia, 74. Servizio Geologico d'Italis, APAT, Rome, Italy

Silva et al., 2008. Catalogue of the geological and environmental effects of earthquakes in Spain in the ESI-2007 Macroseismic scale. Cong. Geol. Esp. Gran Canaria, Spain

Reicherter, K., Michetti, A.M., Silva, P.G., 2009. Paleoseismology: Historical and Prehistorical Record of Earthquake Ground Effects. Geol. Soc. London Spec. Publ. 316. 324 pp. GSL Publishing Hous, London, UK.

This chart is a contribution of the INQUA Focus Area on Paleoseismology and Active Tectonics (TERPRO), developed by the Sapnish Working Group of AEQUA, 2008-2010

Description of ESI intensity degree

X - Very destructive / Effects on the environment become a leading source of hazard and are critical for intensity assessment

Primary effects become leading.
Surface faulting can extend for few tens of km, with offsets from tens of cm up to a few meters. Gravity grabens and elongated depressions develop; for very shallow focus earthquakes in volcanic areas rupture lengths might be much lower. Tectonic subsidence or uplift of the ground surface with maximum values in the order of few meters may occur.

Secondary effects. *The total affected area is in the order of 5000 km².*

a) Many springs significantly change their flow-rate and/or elevation of outcrop. Some springs may run temporarily or even permanently dry. Temporary variations of water level are commonly observed in wells. Even strong variations of chemical-physical properties of water, most commonly temperature, are observed in springs and/or wells. Often water becomes very muddy in even large basins, rivers, wells and springs. Gas emissions, often sulphureous, are observed, and bushes and grass near emission zones may burn.

b) *Meters high waves develop in even big lakes and rivers, which overflow from their beds. In flood plains rivers may change their course, temporary or even permanently, also because of widespread land subsidence. Basins may appear or be emptied. Depending on shape of sea bottom and coastline, tsunamis may reach the shores with runups exceeding 5 m flooding flat areas for thousands of meters inland. Small boulders can be dragged for many meters. Widespread deep erosion is observed along the shores, with noteworthy changes of the coastline profile. Trees nearshore are eradicated and drifted away.*

c) *Open ground cracks up to more than 1 m wide and up to hundred metres long are frequent, mainly in loose alluvial deposits and/or saturated soils; in competent rocks opening reach several decimeters. Wide cracks develop in paved (asphalt or stone) roads, as well as pressure undulations.*

d) *Large landslides and rock-falls (> 10^5 - 10^6 m^3) are frequent, practically regardless to equilibrium state of the slopes, causing temporary or permanent barrier lakes. River banks, artificial embankments, and sides of excavations typically collapse. Levees and earth dams may even incur serious damage. Frequent large landslides under the sea level in coastal areas.*

e) *Trees shake vigorously; many branches and tree trunks break and fall. Some trees might be uprooted and fall.*

f) *Liquefaction, with water upsurge and soil compaction, may change the aspect of wide zones; sand volcanoes even more than 6 m in diameter; vertical subsidence even > 1m; large and long fissures due to lateral spreading are common.*

g) In dry areas, dust clouds may rise from the ground.

h) *Boulders (diameter in excess of 2-3 meters) can be thrown in the air and move away from their site for hundreds of meters down even gentle slopes, leaving typical imprints in soil.*

The characteristics and size of primary effects are corresponding to the earthquake intensity. The role of secondary effects environmental effects.

Text in Italic has been used to highlight descriptions regarded as diagnostic by itself for a given degree.

described i) in terms of total area of distribution for the assessment of epicentral Intensity (starting from intensity VII); ii) grouped in several categories, ordered by the initial degree of occurrence.

ESI 2007 vs traditional intensity scales

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

✓ **From IV to IX:** Environmental effects are easily observable starting from intensity IV, and often permanent and diagnostic especially starting from intensity VII. However, they are necessarily less suitable for intensity assessment than effects on humans and manmade structures. Their use is therefore recommended especially in sparsely populated areas;

✓ **From X to XII**: Effects on humans and manmade structures saturate, while environmental effects become dominant; in fact, several types of environmental effects do not suffer saturation in this range. Thus, environmental effects are the most effective tool to evaluate the intensity.

Diagnostic ranges of intensity degrees

	Environmental effects	Diagnostic range of intensity degrees	
	SURFACE FAULTING AND DEFORMATION	VIII (*)	XII
A	HYDROLOGICAL ANOMALIES	IV	X
B	ANOMALOUS WAVES/TSUNAMIS	IV	XII
C	GROUND CRACKS	IV	X
D	SLOPE MOVEMENTS	IV	X
E	TREE SHAKING	IV	XI
F	LIQUEFACTIONS	V	X
G	DUST CLOUDS	VIII	VIII
H	JUMPING STONES	IX	XII

Epicentral intensity (I_0)

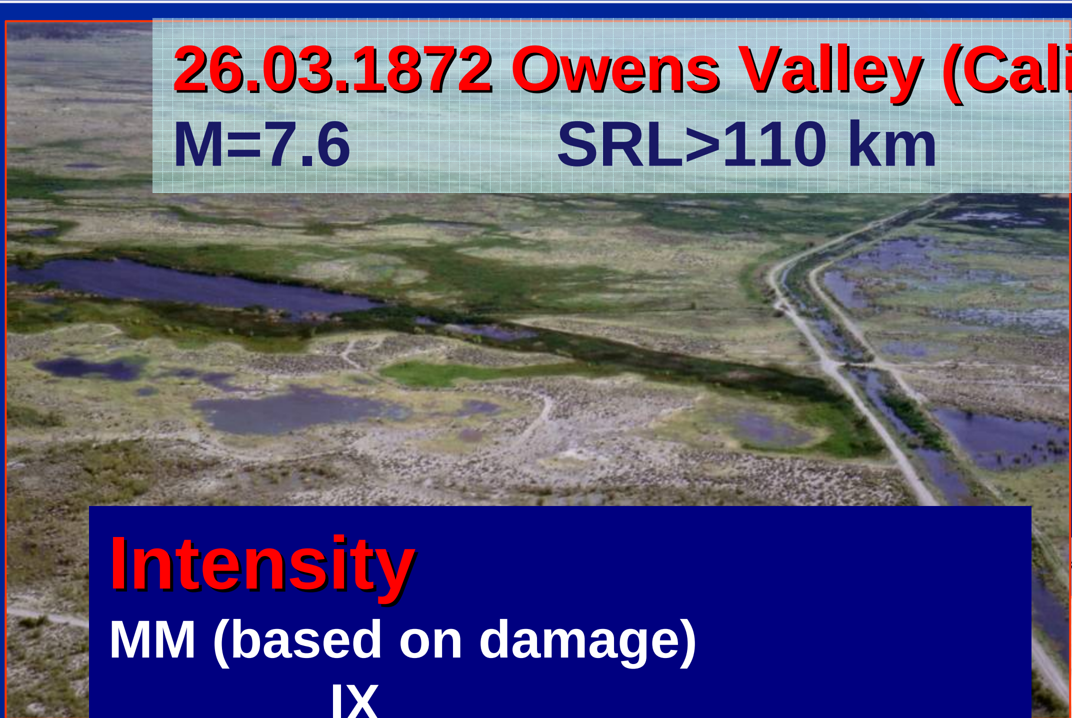
✓ Epicentral intensity (I_0) is defined as the intensity of shaking at epicenter, i.e. what intensity we would get, if there were a locality that matches the epicenter.

✓Surface faulting parameters and total area of distribution of secondary effects (landslides and/or liquefactions) are two independent tools to assess I0 on the basis of environmental effects, starting from the intensity VII.

I_0 Intensity	PRIMARY EFFECTS		SECONDARY EFFECTS
	SURFACE RUPTURE LENGTH	MAX SURFACE DISPLACEMENT / DEFORMATION	TOTAL AREA
IV	-	-	-
V	-	-	-
VI		-	-
VII	(*)	(*)	10 km²
VIII	Several hundreds meters	Centimetric	100 km²
IX	1- 10 km	5 - 40 cm	1000 km²
X	10 - 60 km	40 - 300 cm	5000 km²
XI	60 – 150 km	300 –700 cm	10000 km²
XII	> 150 km	> 700 cm	> 50000 km²

26.03.1872 Owens Valley (California, USA)

M=7.6 SRL>110 km MD≥10m



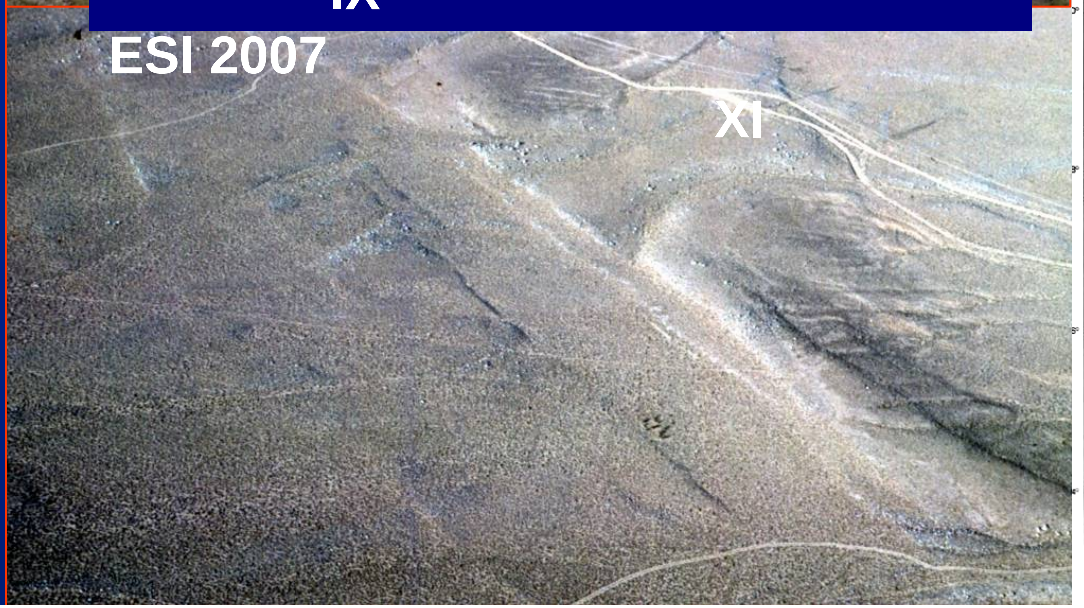
Intensity

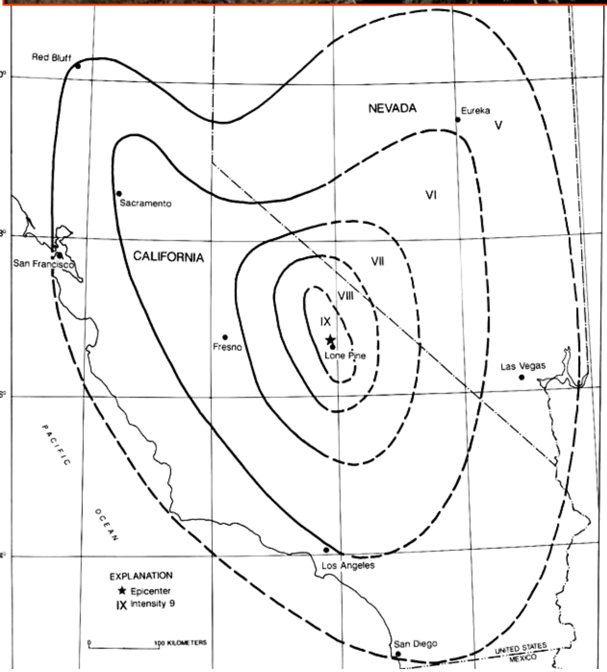
MM (based on damage)

IX

ESI 2007

XI



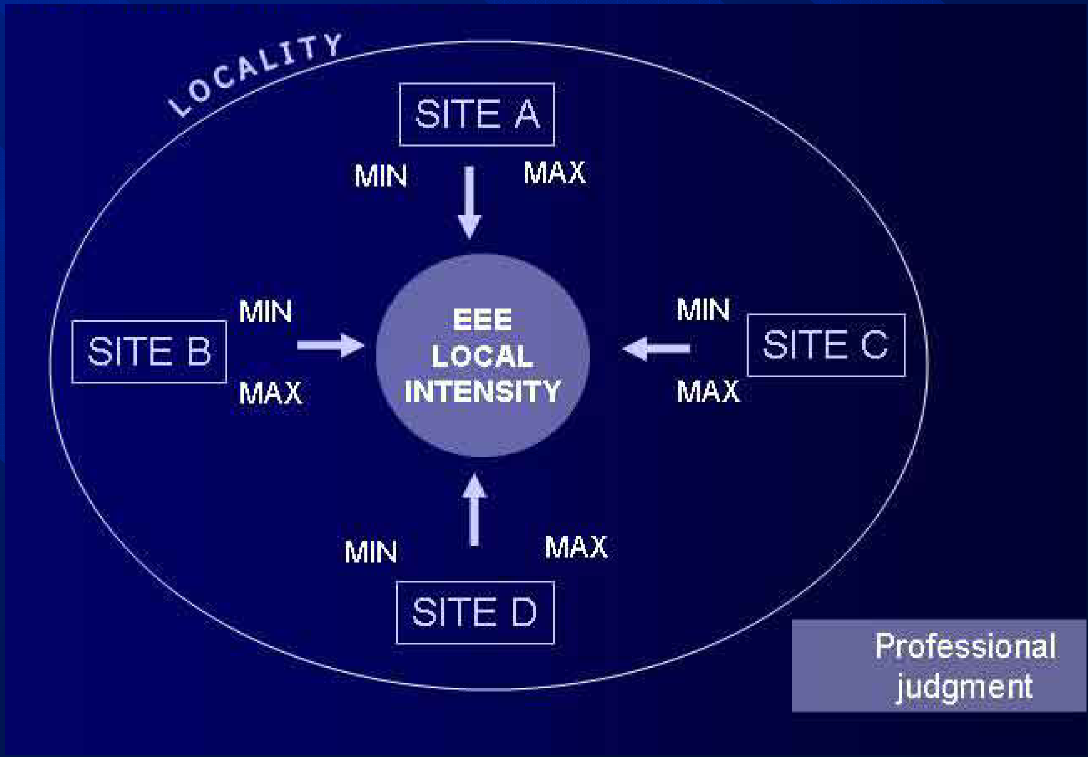


ESI local intensity

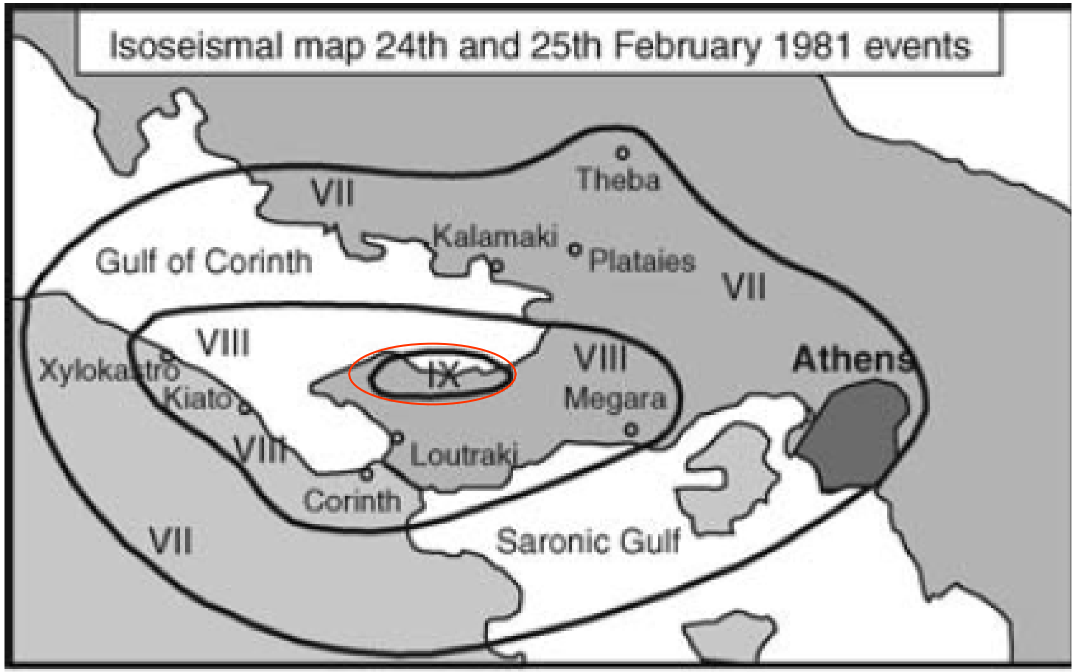
✓ ESI local intensity has to be evaluated at the same scale of the local intensity deriving from traditional macroseismic scales.

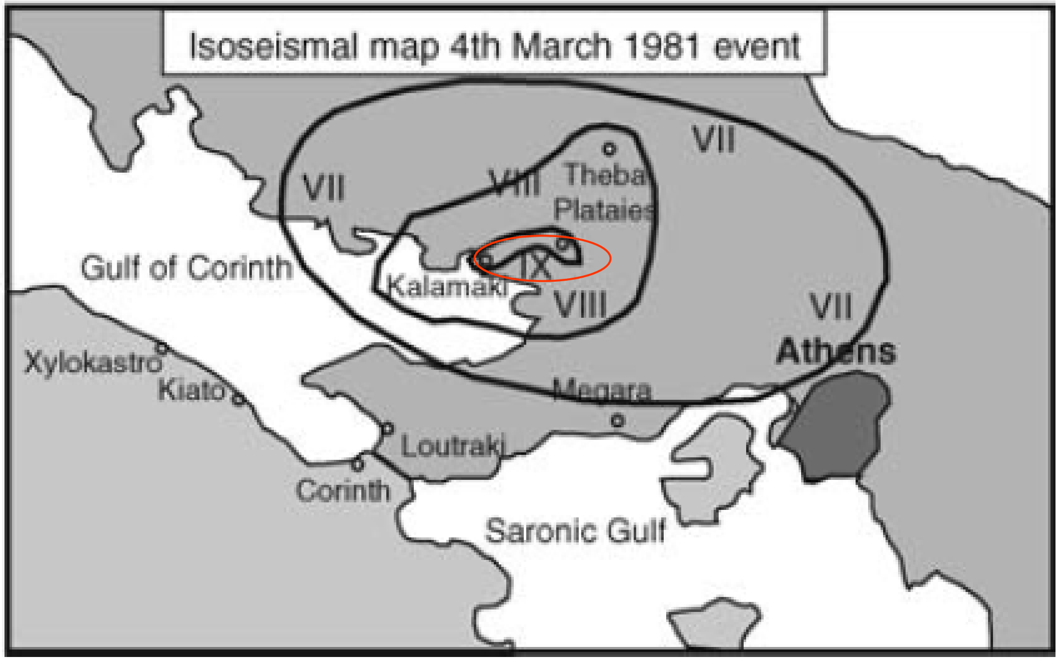
✓ It is generally assessed through the description of secondary effects, but even the local expression of primary effects, in terms of maximum displacement of a fault segment, may contribute to its evaluation.

✓ Since the descriptions of environmental effects are not homogeneously surveyed over the territory, which is common for historical earthquakes, it is recommended to use the Locality – Site approach



1981 Alkyonides earthquake sequence (Ms 6.7, 6.4 and 6.3) (after Papanikolau et al., 2009)





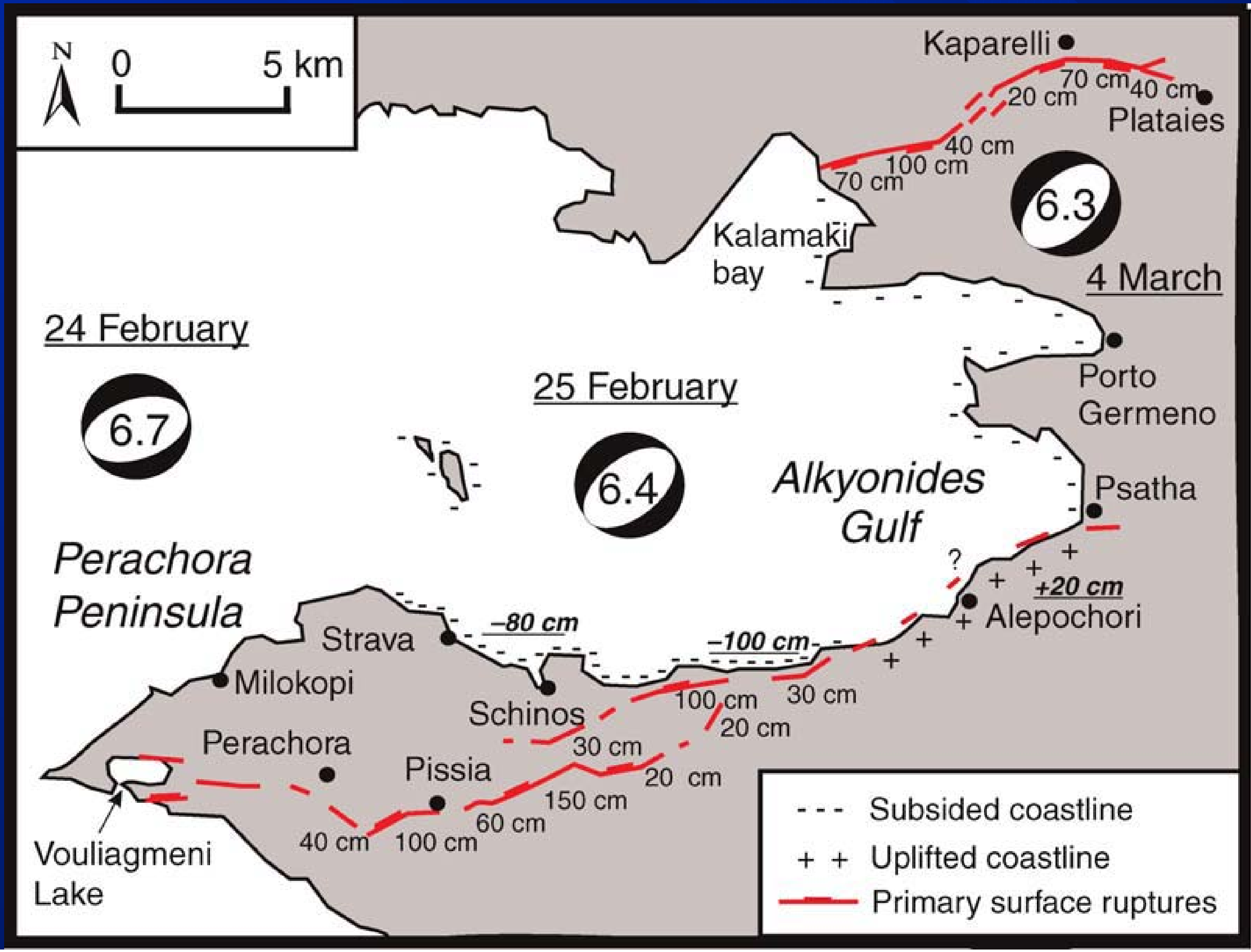
MS intensity distribution (up to IX)

West of Alepochori 50–60 cm of subsidence was observed, flooding up to 50 m of the former shore (Mariolakos et al. 1982).

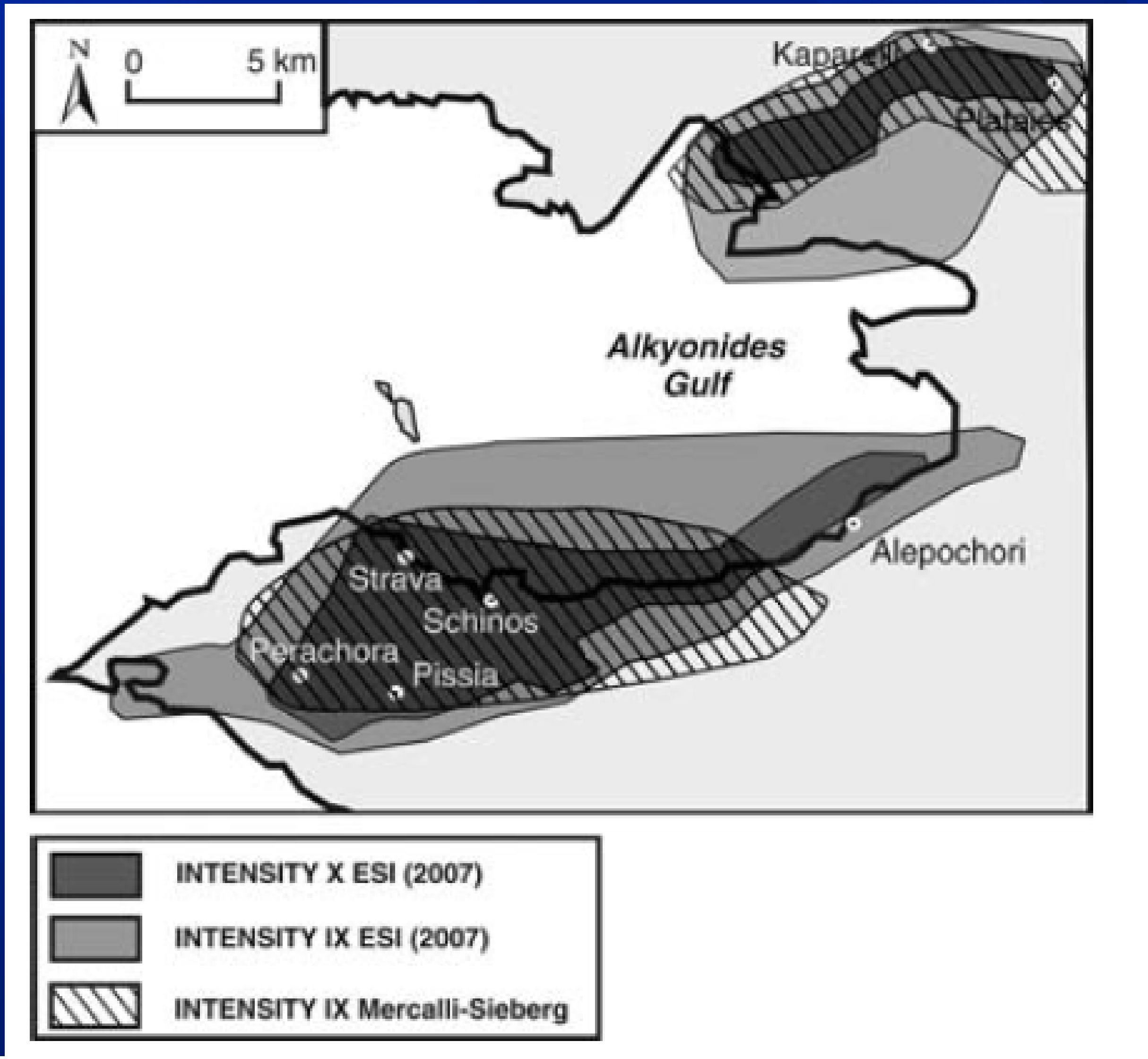
Surface ruptures on the Plataies–Kaparelli fault zone during the 4 March event, producing 50–60 cm of throw (70 cm of displacement).

VIII Heavily damaging – Extensive effects on the environment	IX Destructive – Environmental effects are a widespread source of considerable hazard and become important for intensity assessment	X Very destructive – Effects in the environment become a leading source of hazards and are critical for intensity assessment
Primary effects observed rarely. Ground ruptures (surface faulting) may develop, up to several hundred meters long, with offsets not exceeding a few cm, particularly for very shallow focus earthquakes. Tectonic subsidence or uplift with maximum values on the order of a few centimetres may occur.	Primary effects observed commonly. Ground ruptures (surface faulting) develop, up to a few km long, with offsets generally in the order of several cm. Tectonic subsidence or uplift of the ground surface with maximum values in the order of a few decimetres may occur.	Primary ruptures become leading. Surface faulting can extend for few tens of km, with offsets from tens of cm up to a few metres. Gravity grabens and elongated depressions develop; Tectonic subsidence or uplift with maximum values in the order of few meters may occur.

1981 Alkyonides surface faulting distribution



Comparison between MS and ESI 2007 intensities



Added value of ESI 2007

✓ The ESI 2007 added value is particularly clear in case damages to buildings:

1) are lacking, such as in desert or sparsely populated areas;

2) suffer from saturation, i.e. the earthquake causes the total collapse of buildings (X intensity degree in Italy).

In these cases, effects on natural environment are the best tool, often the only one, to "measure" the earthquake intensity.

✓ Moreover, intensity values based on environmental effects are more widely comparable than damages to buildings since they are not influenced by local socio-economic conditions.

✓ Some environmental morphogenetic effects can be stored in the paleoseismological record, allowing to expand the time window for seismic hazard assessment up to tens of thousands of years.

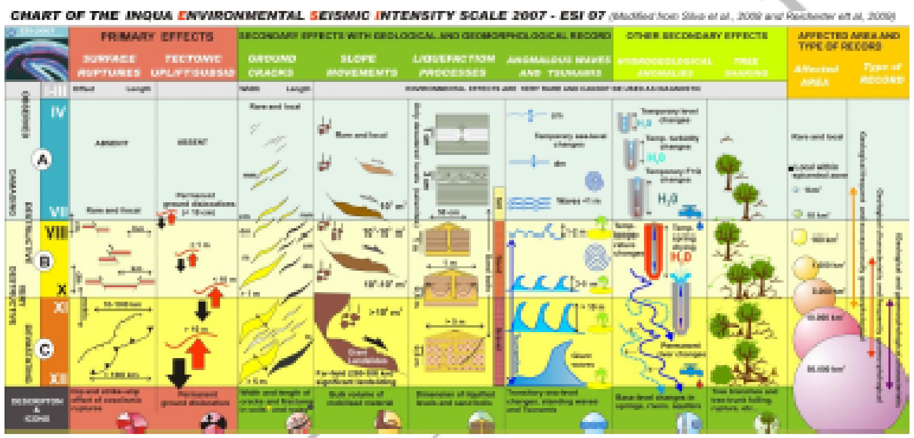
Translated in eight languages

- ✓ Environmental Seismic Intensity Scake – ESI 2007
- ✓ La scala di intensità sismica ESI 2007
- ✓ Escala medio-ambiental de intensidad sismica ESI 2007
- ✓ ESI 2007 Intensitätsskala
- ✓ ESIの2007年の震度
- ✓ Шкала сейсмической интенсивности на основании природн эффектов – ESI 2007
- ✓ Η μακροσεισμική κλίμακα έντασης ESI 2007
- ✓ Seismische intensiteitschaal op basis van omgevingseffecte

Earthquake Environmental Effects,

intensity and seismic hazard assessment:

the ESI intensity scale and the EEE Catalogue



Memorie Descrittive Carta Geologica d'Italia

Vol. xyz

2011

DRAFT

✓Available on-line at

http://www.isprambiente.gov.it/site/en-GB/Projects/INQUA_Scale/Documents_/

EEE Catalogue

The EEE Catalogue:

A catalogue of Earthquake Environmental Effects

INQUA
International Union for Quaternary Research

INQUA TERPRO project 0811

Why the EEE Catalogue is timely?

- ✓A huge amount of information of EEEs in now available
- ✓Lessons from recent earthquakes clearly pointed out the relevance of EEEs for SHA purposes
- ✓The recent development of web GIS applications and geograohic interface based on Google Earth allow to disseminate collected data over a geographic interface.

Objective

To collect in a standard format the wealth of information of environmental / geological effects induced by seismic events, in order to:

- ✓ bridge a gap between recent, historical and paleoearthquakes;
- ✓ allow a more objective comparison among them, taking advantage from the application of the ESI scale.

Data sources

- ✓ Surveys on EEEs (from remote and field observations)
- ✓ Historical contemporary documents
- ✓ Paleoseismological papers

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Yolanda Zamudio (Peru) , Kervin Chunga (Ecuador), Ioannis Papanikolau (Greece)

and many others.....

Web Implementation interface

http://www.eeecatalog.sinanet.apat.it/login.php

Page 1 of 4 Records 1 to 20 of 62 Page Size 20

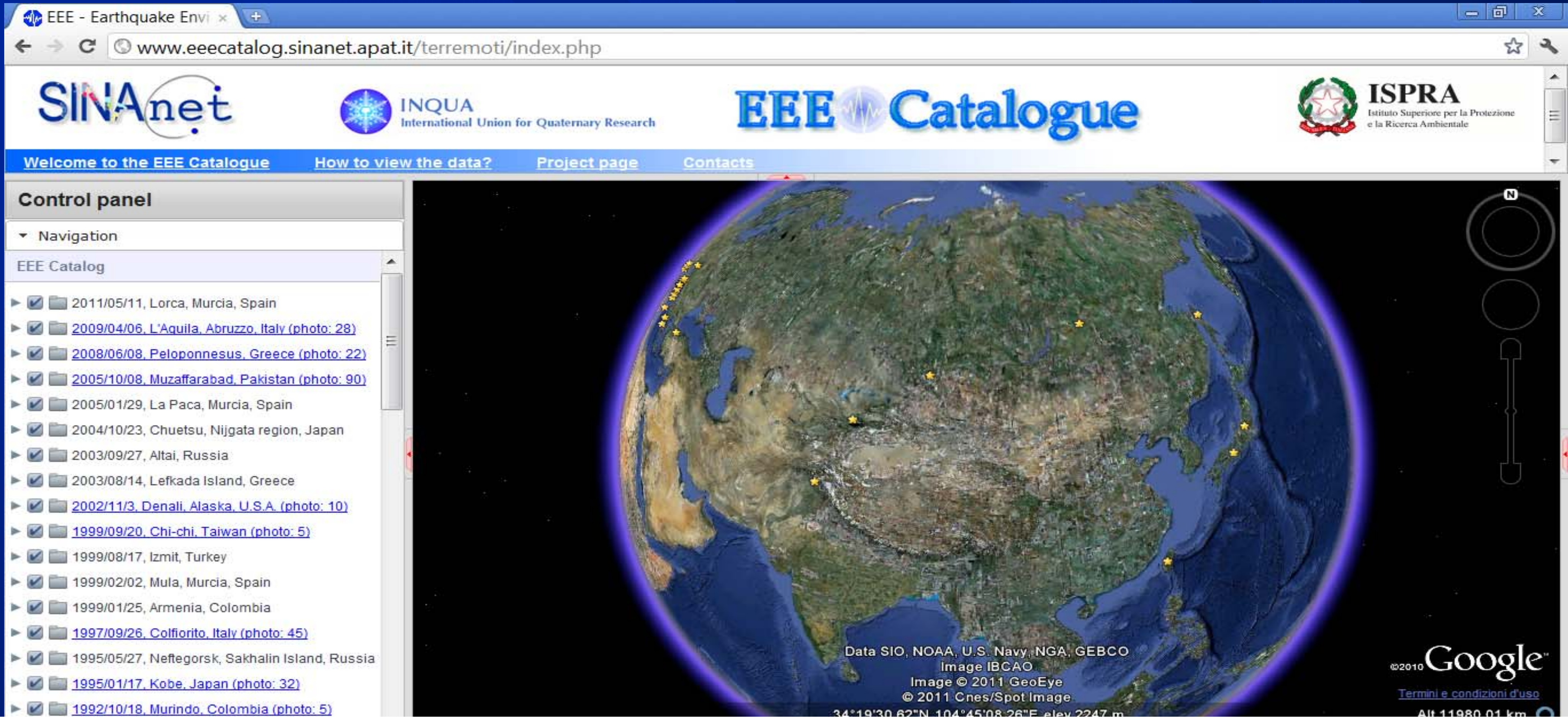
Add

Age Earthquake	Earthquake Code (*)	Year	Month (*)	Day (*)	Epicentral Area (*)	Country	Surface faulting type	Magnitude (*)	Magnitude Type (*)	Intensity Type	ESI Epicentral Intensity	Reference for seismologic data	Authors
Instrumental	SP20110511	2011	05	11	Lorca, Murcia	Spain	Hypotesized based on site observations	5.1	Mw	EMS	7		P.G. Silva Rodríguez Pascua, Pérez Lóp J.J. Martí Díaz
Instrumental	IT20090406m	2009	04	06	L'Aquila, Abruzzo	Italy	Surveyed rupture zone	6.3	Mw	MCS	9	Chiarabba et al., 2009	Lippmann
Instrumental	GR20080608m	2008	06	08	Peloponnesus	Greece	Surveyed rupture zone	6.4	Mw	EMS	9	Koukouvelas et alii, 2010	Lucarini M Brustia E
Instrumental	CH20080512m	2008	05	12	Wenchuan	China		7.9	Mw	EMS	12		E. Lekkas
Instrumental	PK20051008m	2005	10	08	Muzaffarabad	Pakistan		7.6	Mw	MM	11		Ali, Miche A.M. Riga E.
Instrumental	SP20050129	2005	01	29	La Paca, Murcia	Spain		4.8	Mb	EMS	6		P.G. Silva
Instrumental	JP20041023m	2004	10	23	Chuetsu, Nijgata region	Japan		6.6	Mw	JMA			Ota Y. & Azuma T.
Instrumental	IS20040211	2004	02	11	Northern Dead Sea	Israel							A. Salam
Instrumental	GR20030814m	2003	08	14	Lefkada Island	Greece		6.2	Mw	EMS	8		Papathan G.
Instrumental	RU20030927m	2003	09	27	Altai	Russia		7.2	Mw	MSK	10	ISC	R.E. Tatevoss
Instrumental	US20021103m	2002	11	3	Denali, Alaska	U.S.A.	Surveyed rupture zone	7.9	MW			Donna Eberhart-Phillips, et al., 2003	Banfi D., Comerci Michetti
Instrumental	TW19990920m	1999	09	20	Chi-chi	Taiwan	Surveyed rupture	7.3	Mw	JMA	11	CWB99	Lin-Wong

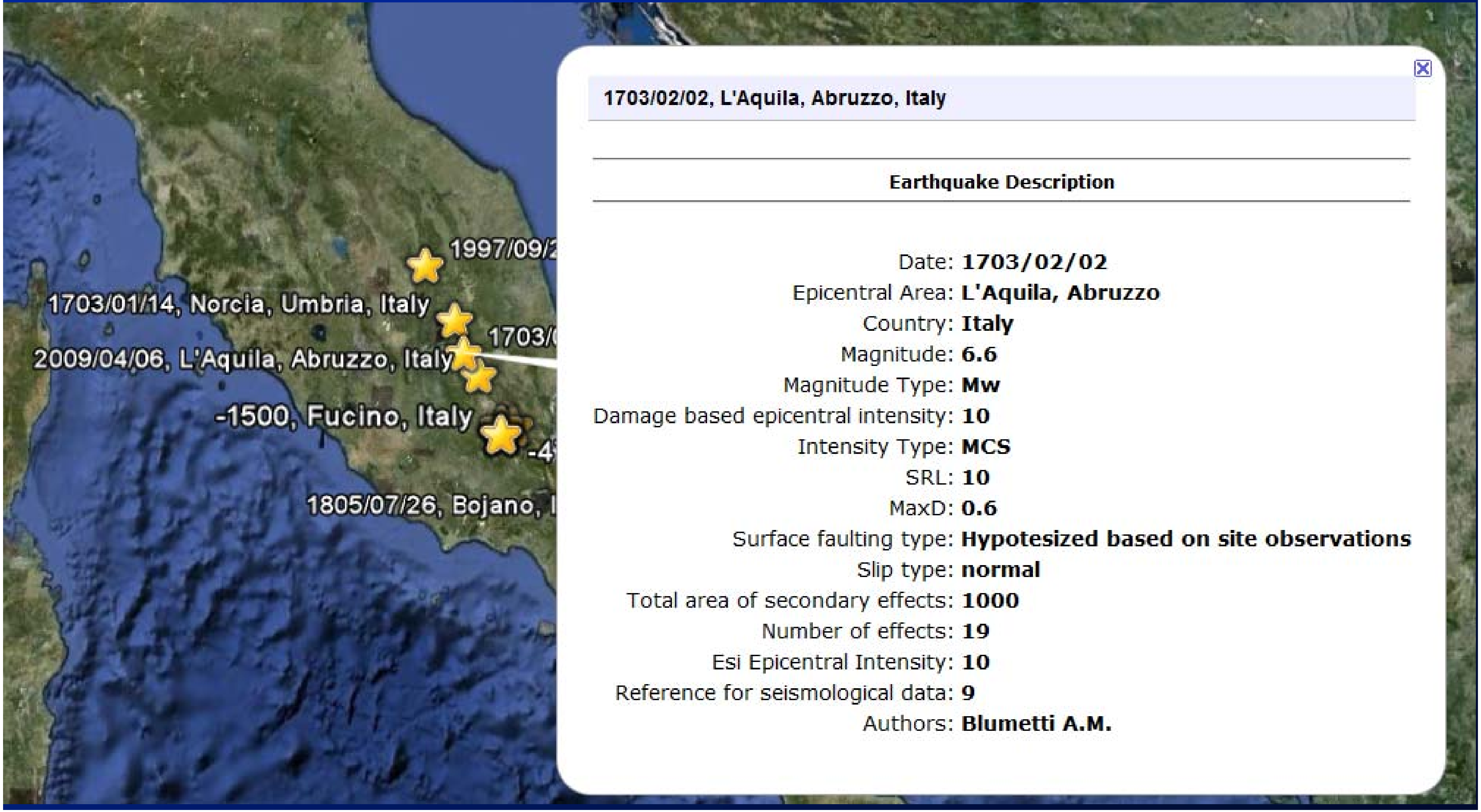
Public Viewing interface

http://www.eeecatalog.sinanet.apat.it/terremoti.php

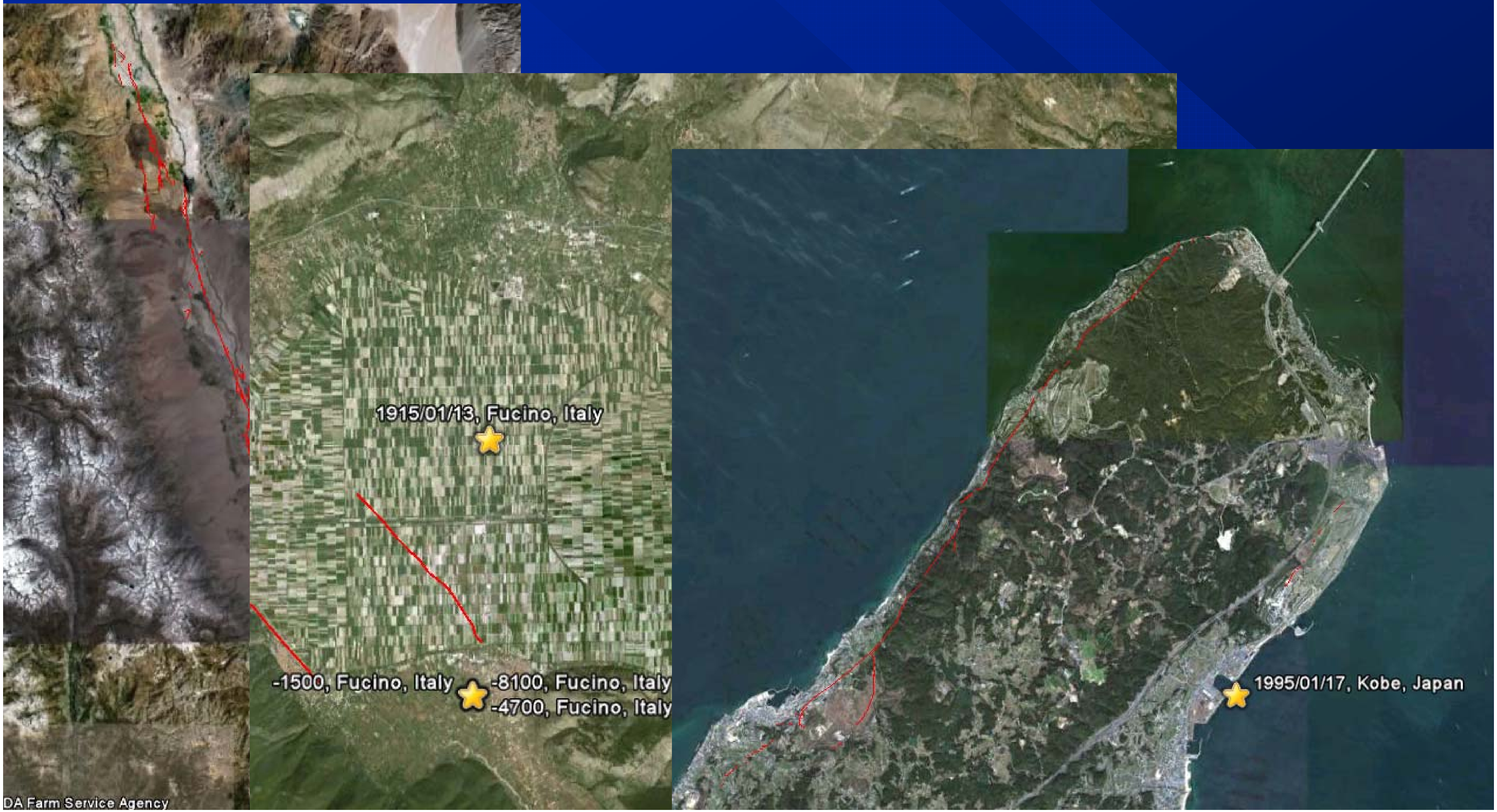
Public version of the EEE Catalogue based on Google Earth



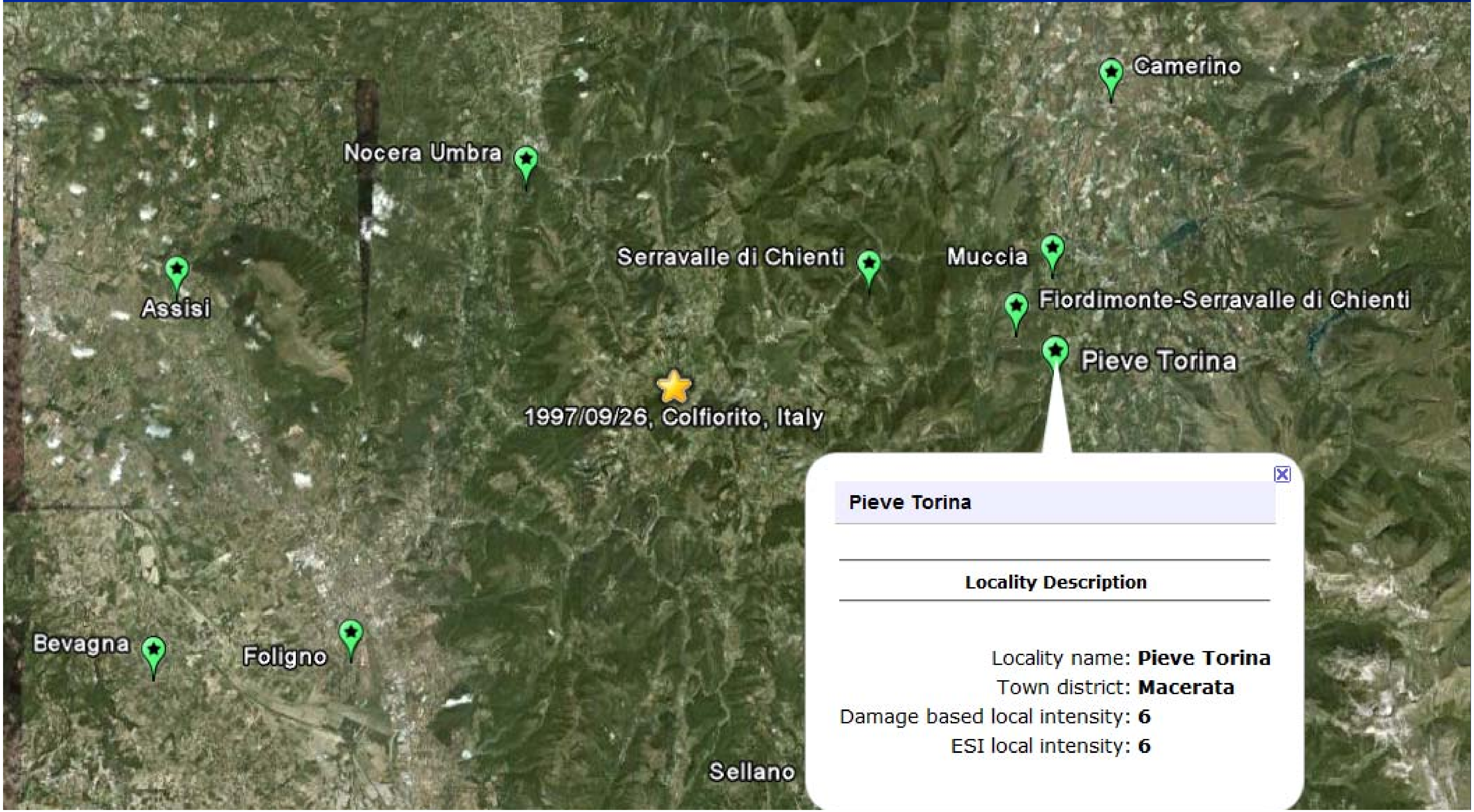
EARTHQUAKE LEVEL: SUMMARY DESCRIPTION



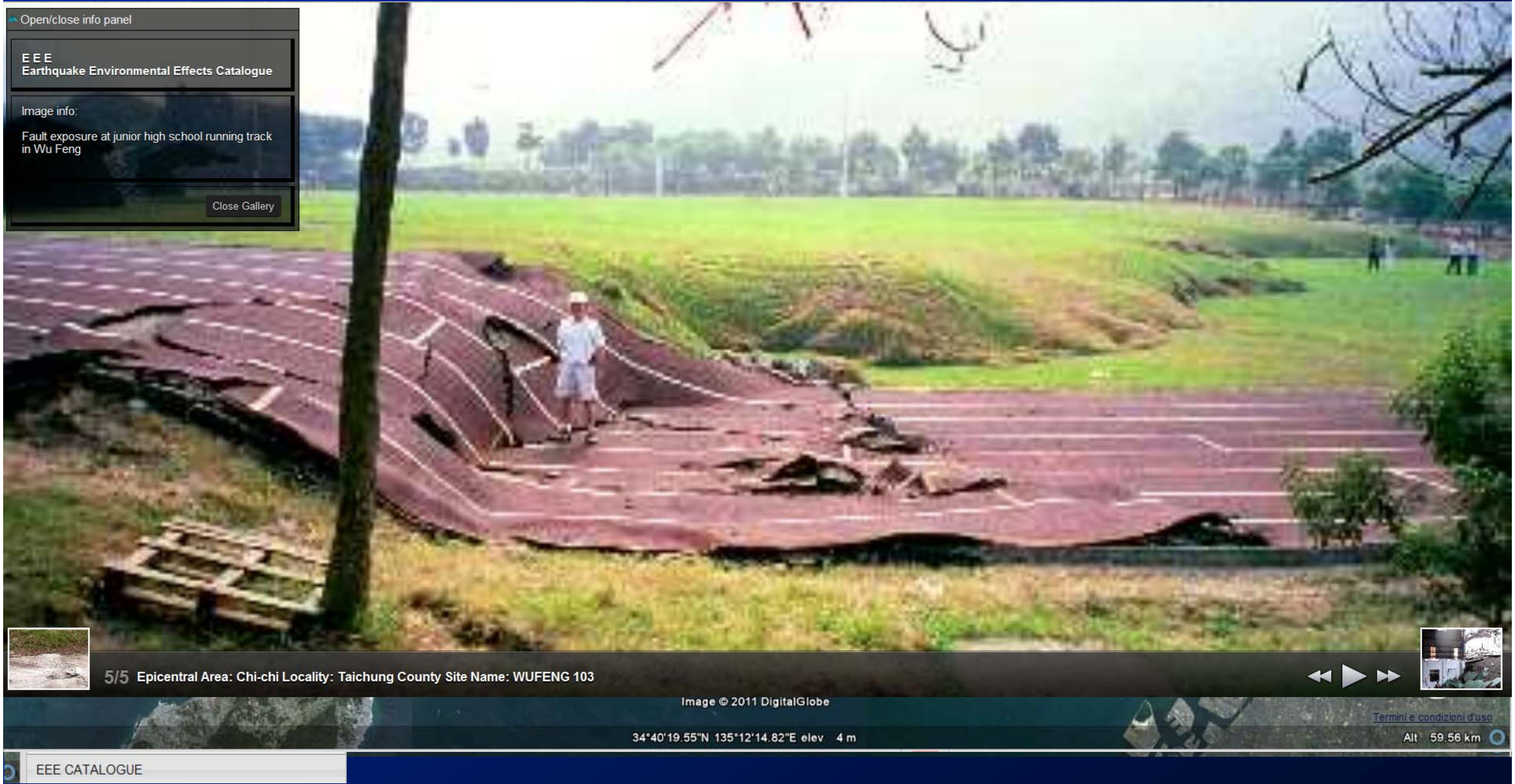
EARTHQUAKE LEVEL: RUPTURE ZONES



LOCALITY LEVEL: LOCAL INTENSITIES



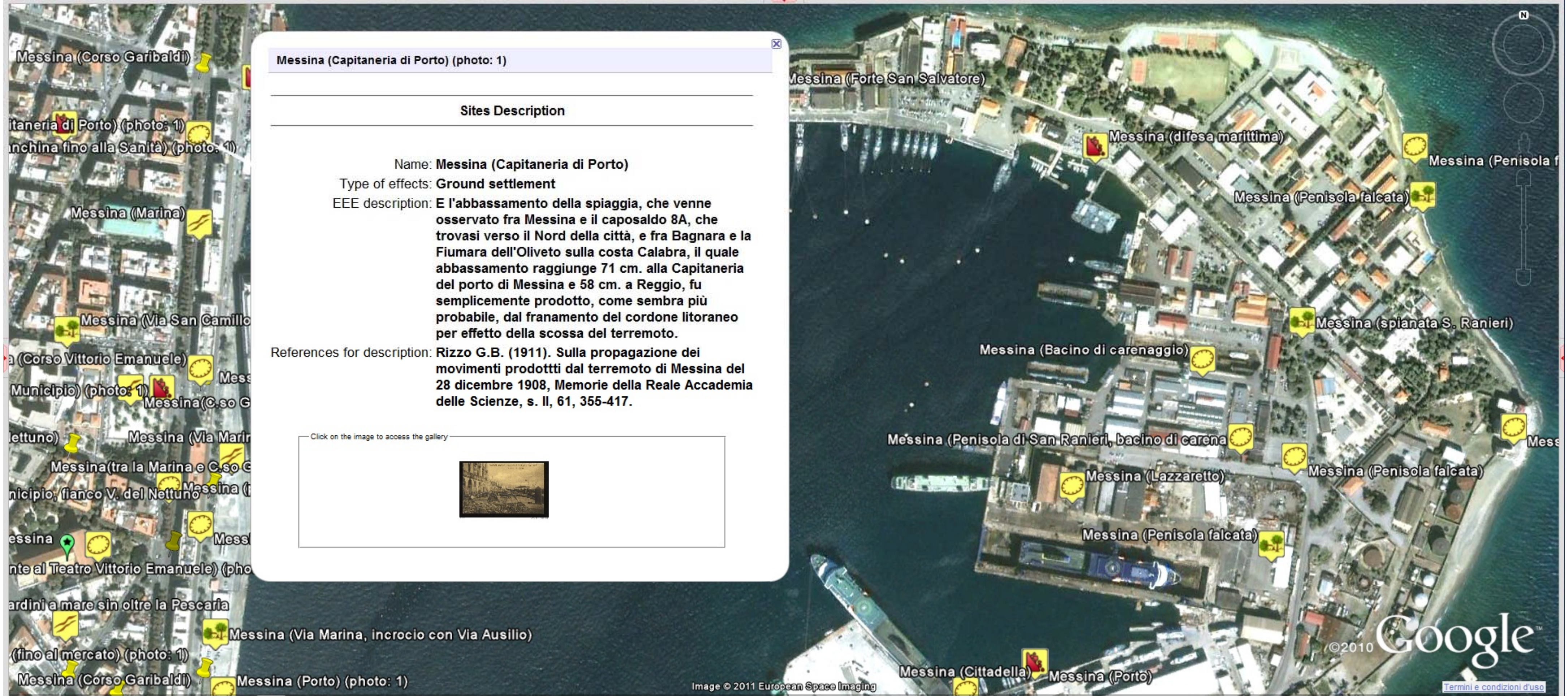
SITE LEVEL: EEE DESCRIPTION



Added value

The EEE Catalogue will point out:

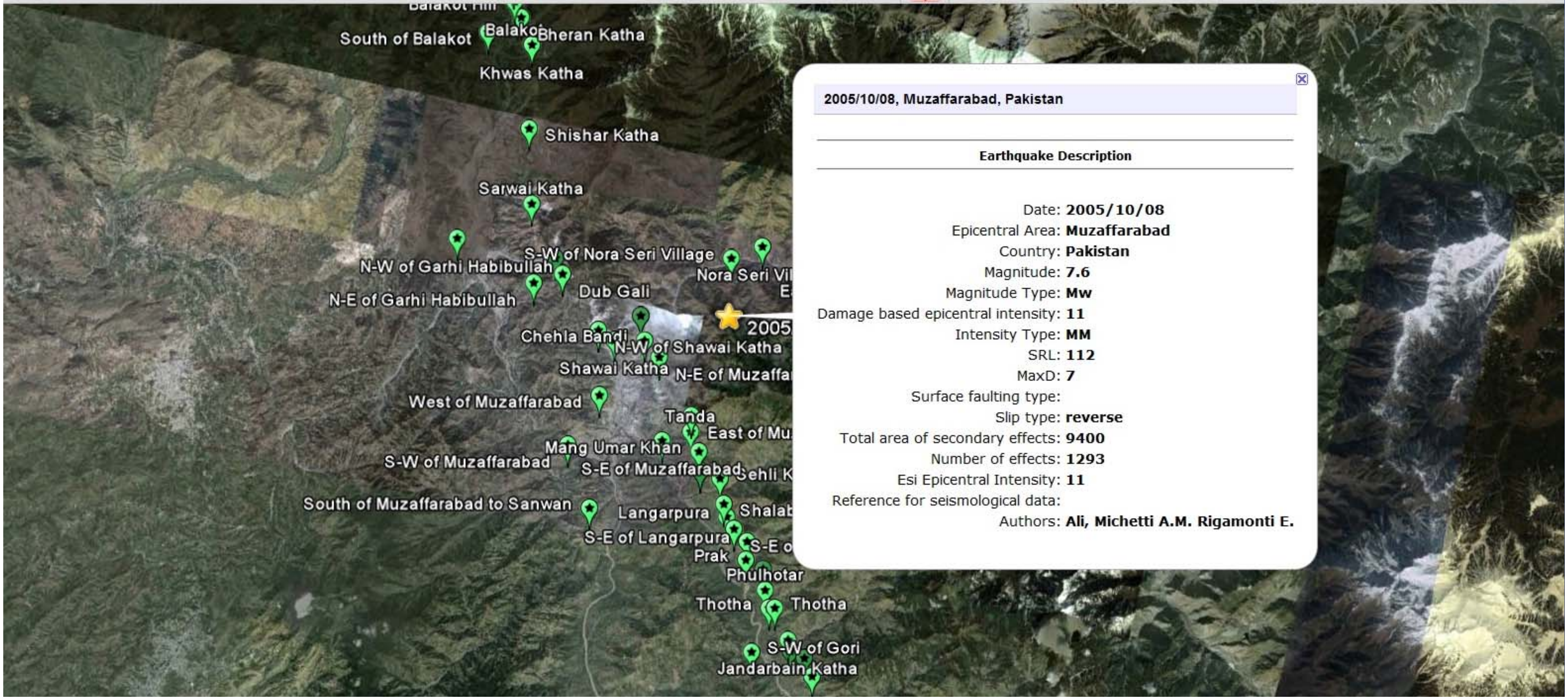
- the most vulnerable zones in terms of EEEs in an area hit by a strong earthquake;



Added value

The EEE Catalogue will point out:

- an independent seismic intensity evaluation through the ESI scale.



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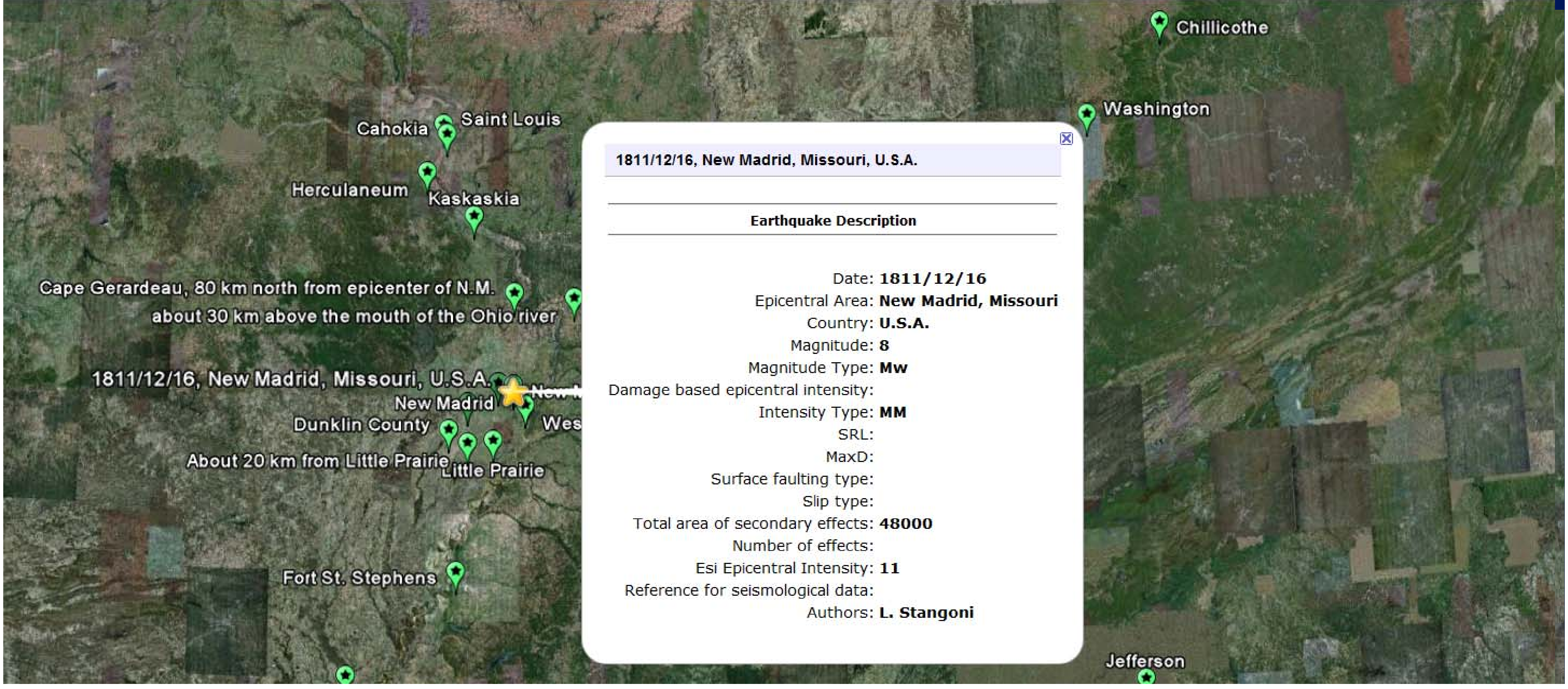

Some examples

- 2009 L'Aquila
- 1703 L'Aquila
- 1980 Irpinia
- 2002 Murindo
- 2003 Lefkada

Final remarks

- Recent earthquakes have confirmed the primary role of EEEs for SHA;
- The EEE Catalogue infrastructure is ready for a standard data collection of EEEs. It is a very helpful tool in emergency conditions;
- It will be always under implementation. But it needs to identify priorities in data collection (geographic, temporal, magnitude threshold, type of effects, etc.);
- Potential links with other initiatives encourage this data collection effort.