IAEA ANSN / ISSC - REGIONAL WORKSHOP ON

"Volcanic, Seismic, and Tsunami Hazard Assessment Related to NPP Siting Activities and Requirements"

Jakarta, Indonesia, 13-17 June 2011

"Collection and interpretation of geological, geophysical and geotechnical data – Geological Database and Seismotectonic Model "

Alessandro Maria Michetti

INTERNATIONAL SEISMIC SAFETY CENTRE, NSNI/IAEA

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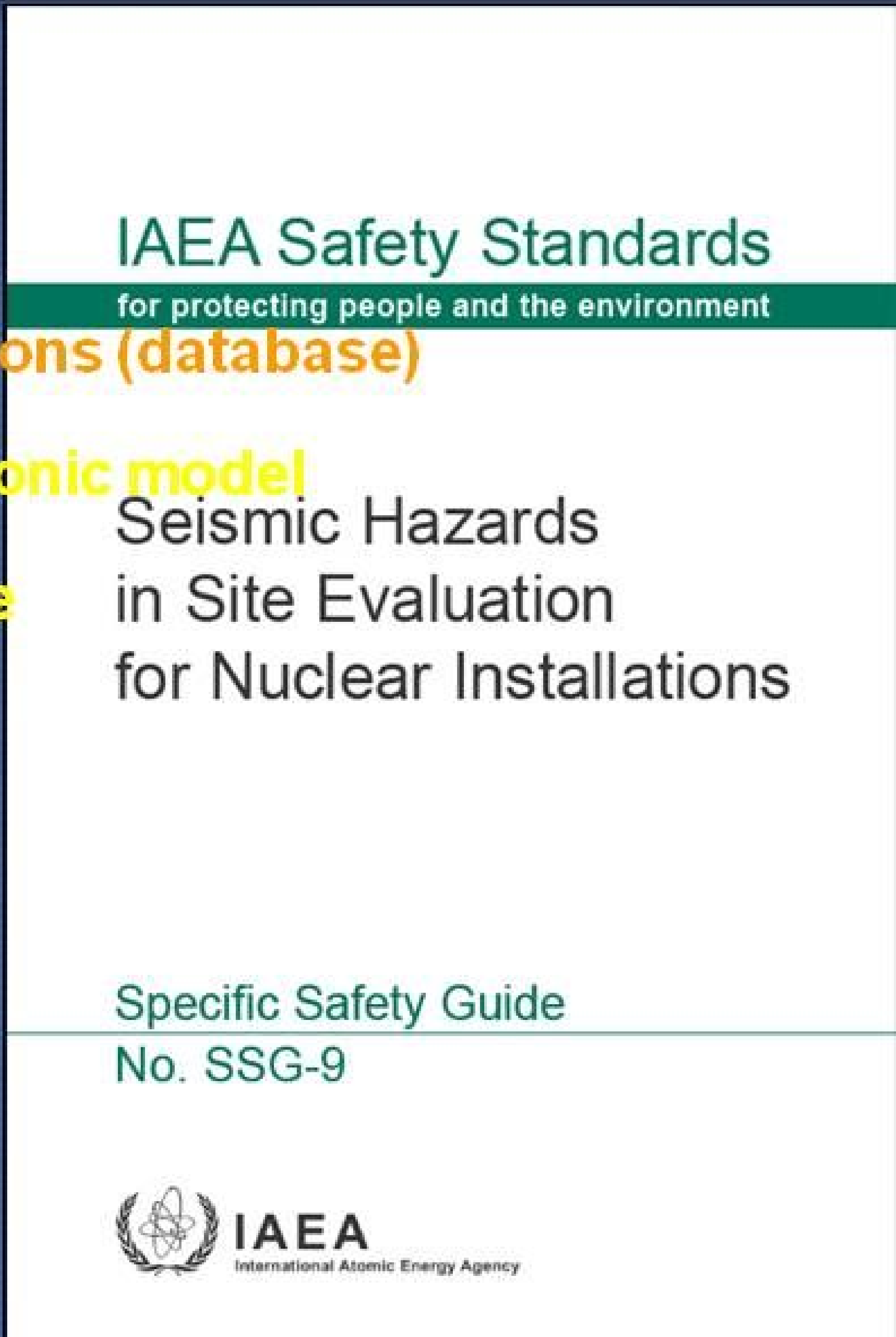
International Atomic Energy Agency

Lecture 5

SUMMARY

- Introduction
- General recommendations
- Necessary information and investigations (database)
- Construction of a regional seismotectonic model
- Potential for surface faulting at the site



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Necessary information and investigations (database)

OVERVIEW

3.1. A comprehensive and integrated database should be acquired which incorporates in a coherent form the information needed to evaluate and resolve issues relating to all hazards associated with earthquakes.

3.2. It should be ensured that each element of every practical database has been investigated as fully as possible before integration of the various elements is attempted. The integrated database should include all relevant information; that is, not only geological, geophysical, geotechnical and seismological data, but also any other information that is relevant to evaluating the ground motion, faulting and geological hazards at the site.

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Necessary information and investigations (database)

SCALES OF INVESTIGATIONS

Site vicinity

Objectives:
- Neotectonic fault history
- Potential for surface faulting

Near regional scale

Objectives:
- Detailed seismotectonic characterization
- Latest faults movements

Regional scale

Objectives:
- General geodynamic setting
- Characterization of geological features
- Delineation of seismogenic sources

Site area (~1 km^2)

5 km (maps scale 1:5 000)

25 km (maps scale 1:50 000)

>300 km (maps scale 1:500 000)

A need for application of increased efforts

The first three scales of investigation lead primarily to progressively more detailed geological and geophysical data and information. The site area investigations are aimed at developing the geotechnical database.

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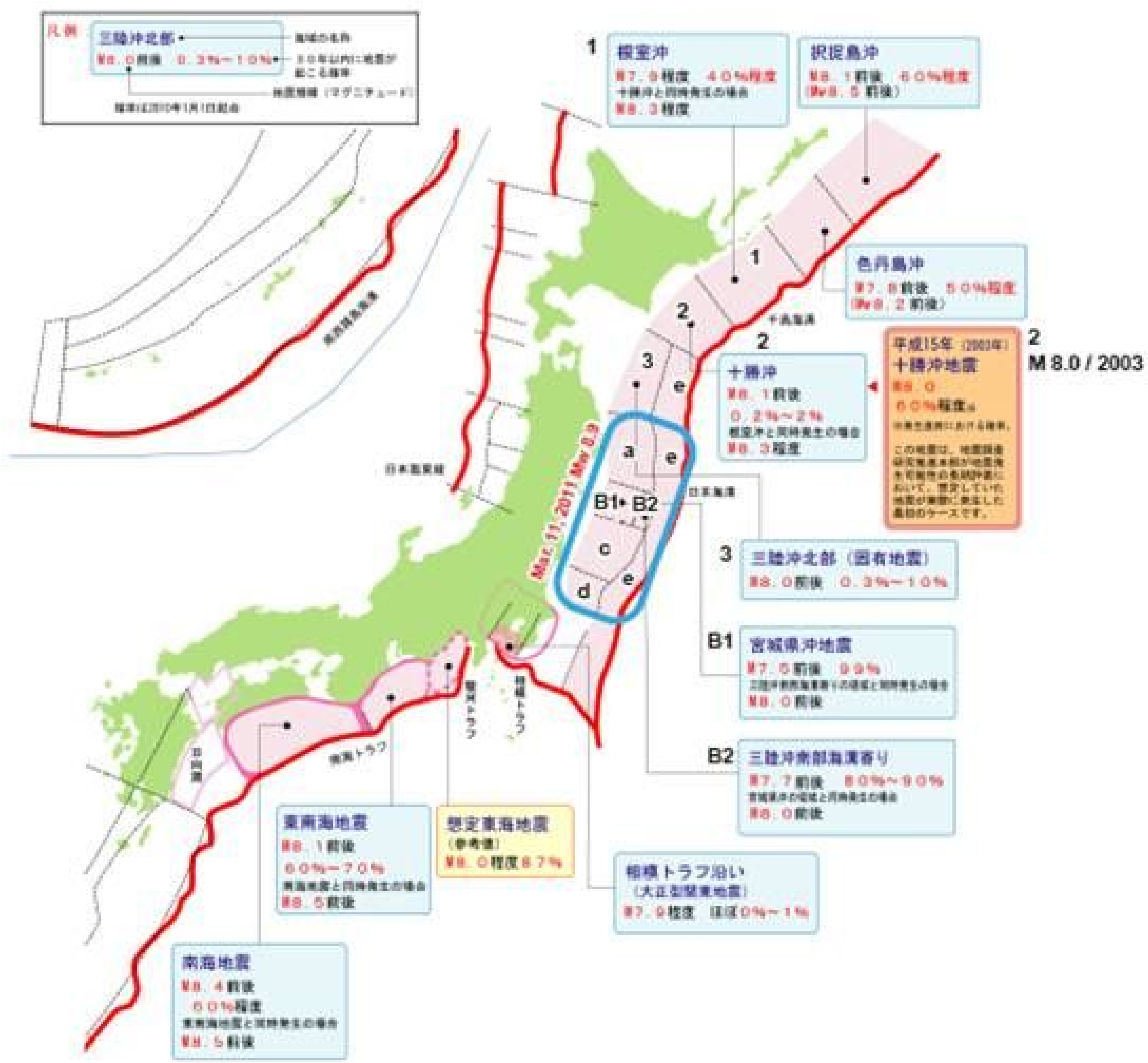
Modified after Japan HERP - Headquarters for Earthquake Research Promotion, 2009

Japnaese Hazard Map category I: Eqrthquakes from SPECIFIC source with 100s year recurrence interval. http://www.jishin.go.jp/main/chousa/10_yosokuchizu/k_jishincategory.pdf P. 28 with additional information (Mar. 11, 2011 source area, segment 1, 2, 3, a, B1, B2, b, c, d, and e) by Koji.

解説：地震カテゴリー

カテゴリーＩの地震の長期評価結果の概要

カテゴリーＩの地震、すなわち、海溝型地震のうち震源断層を特定できる地震（震源断層を予め特定でき、再来間隔が数百年オーダーの地震）の長期評価結果の概要を以下に示す。



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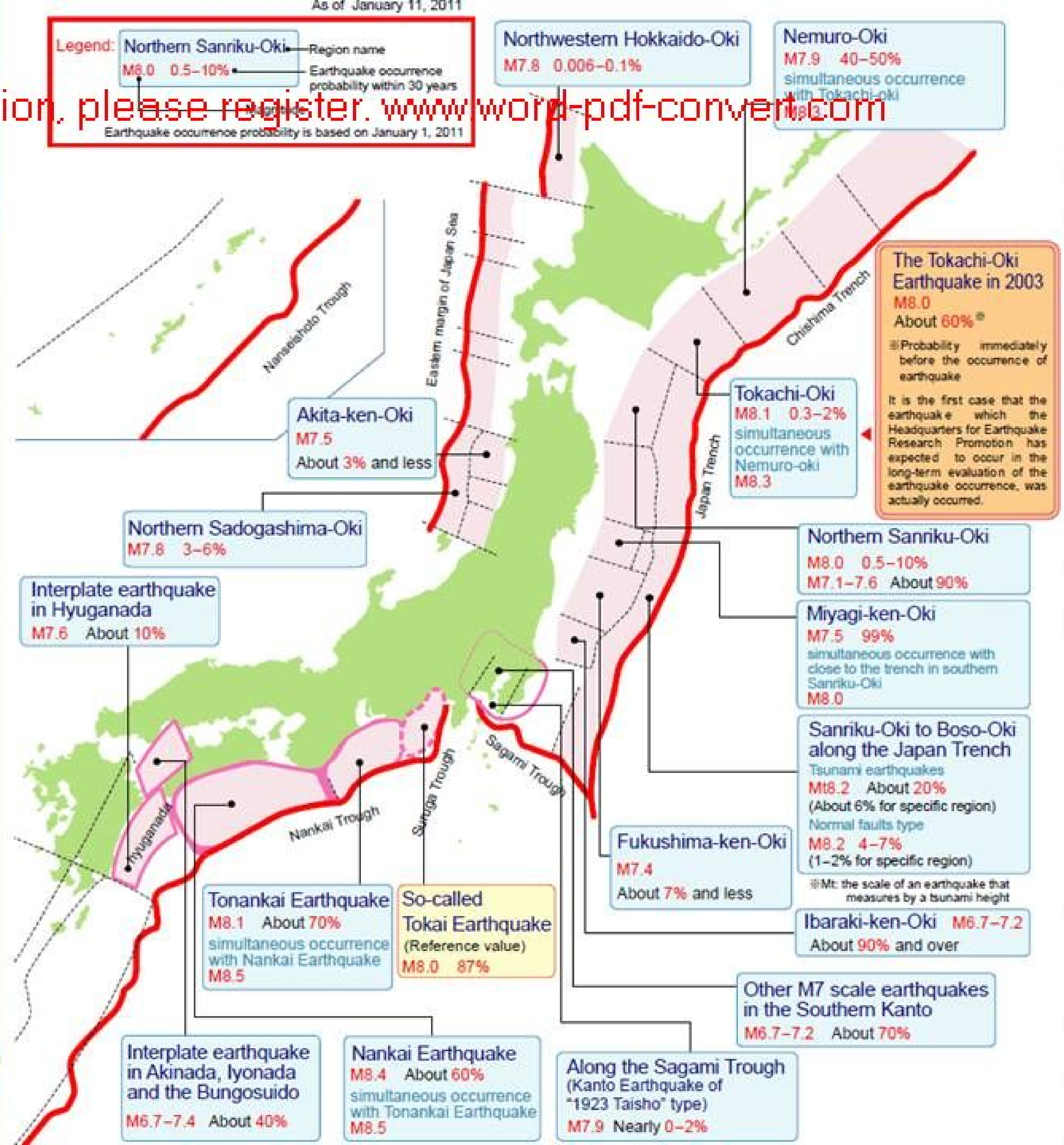

As of January 11, 2011
Legend: Northern Sanriku-Oki — Region name
M8.0 0.5–10% — Earthquake occurrence probability within 30 years
Earthquake occurrence probability is based on January 1, 2011
Northwestern Hokkaido-Oki
M7.8 0.006–0.1%
Nemuro-Oki
M7.9 40–50%
simultaneous occurrence with Tokachi-oki
M8.3
The Tokachi-Oki Earthquake in 2003
M8.0
About 60%
※Probability immediately before the occurrence of earthquake
It is the first case that the earthquake which the Headquarters for Earthquake Research Promotion has expected to occur in the long-term evaluation of the earthquake occurrence, was actually occurred.
Tokachi-Oki
M8.1 0.3–2%
simultaneous occurrence with Nemuro-oki
M8.3
Chishima Trench
Japan Trench
Eastern margin of Japan Sea
Nanseishoto Trough
Akita-ken-Oki
M7.5
About 3% and less
Northern Sadogashima-Oki
M7.8 3–6%
Northern Sanriku-Oki
M8.0 0.5–10%
M7.1–7.6 About 90%
Miyagi-ken-Oki
M7.5 99%
simultaneous occurrence with close to the trench in southern Sanriku-Oki
M8.0
Sanriku-Oki to Boso-Oki along the Japan Trench
Tsunami earthquakes
Mt8.2 About 20%
(About 6% for specific region)
Normal faults type
M8.2 4–7%
(1–2% for specific region)
※Mt: the scale of an earthquake that measures by a tsunami height
Interplate earthquake in Hyuganada
M7.6 About 10%
Hyuganada
Nankai Trough
Suruga Trough
Sagami Trough
Fukushima-ken-Oki
M7.4
About 7% and less
Ibaraki-ken-Oki M6.7–7.2
About 90% and over
Tonankai Earthquake
M8.1 About 70%
simultaneous occurrence with Nankai Earthquake
M8.5
So-called Tokai Earthquake
(Reference value)
M8.0 87%
Other M7 scale earthquakes in the Southern Kanto
M6.7–7.2 About 70%
Interplate earthquake in Akinada, Iyonada and the Bungosuido
M6.7–7.4 About 40%
Nankai Earthquake
M8.4 About 60%
simultaneous occurrence with Tonankai Earthquake
M8.5
Along the Sagami Trough
(Kanto Earthquake of "1923 Taisho" type)
M7.9 Nearly 0–2%

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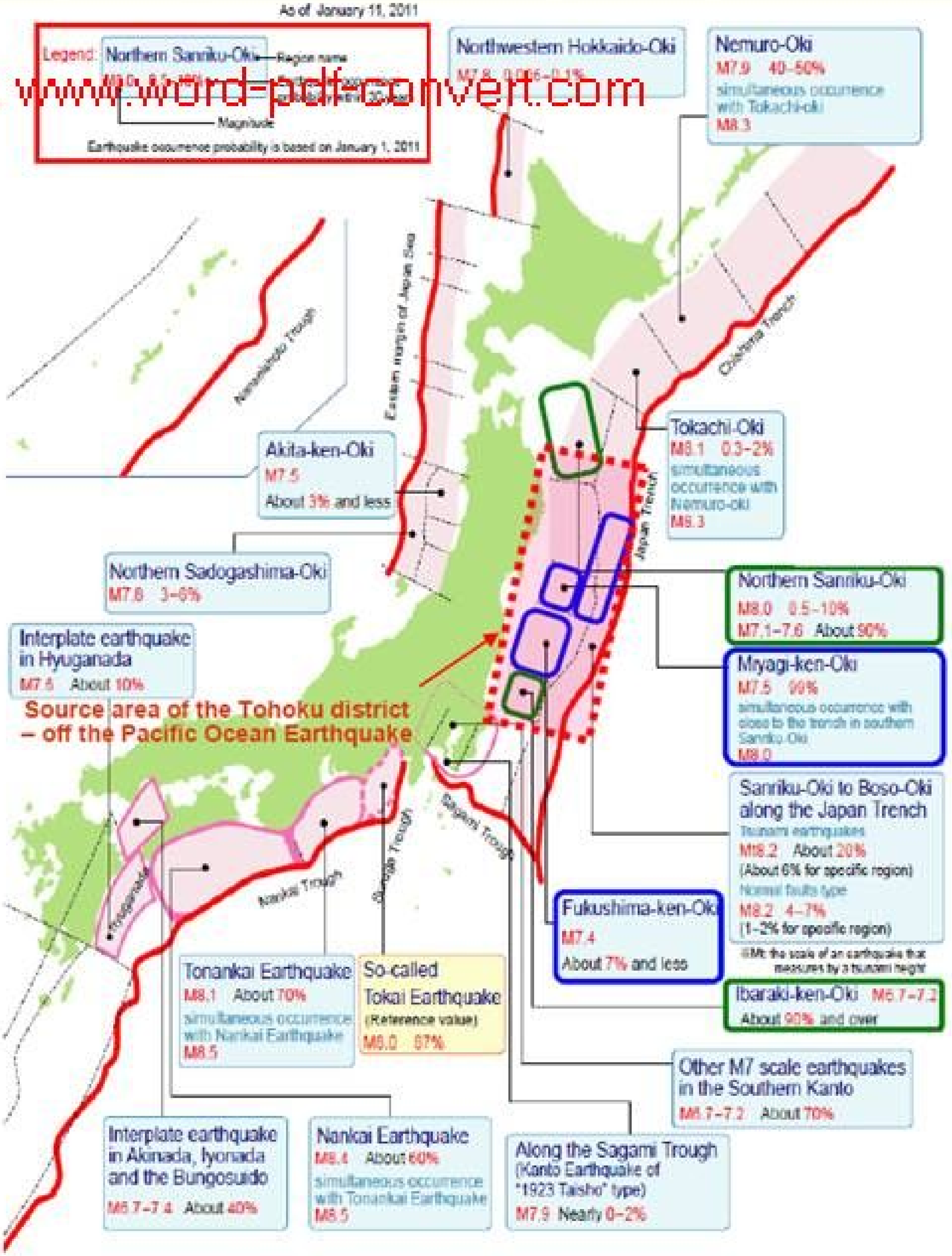
Comparison of the source areas of the main shock and scenario earthquakes evaluated by Long-Term Evaluation Subcommittee, Earthquake Research Committee, Headquarters for Earthquake Research Promotion (HERP).



Reference: Earthquake Research Comit., HERP Release [Online]. http://www.jishin.go.jp/main/index-e.html
Partially modified by JNES.

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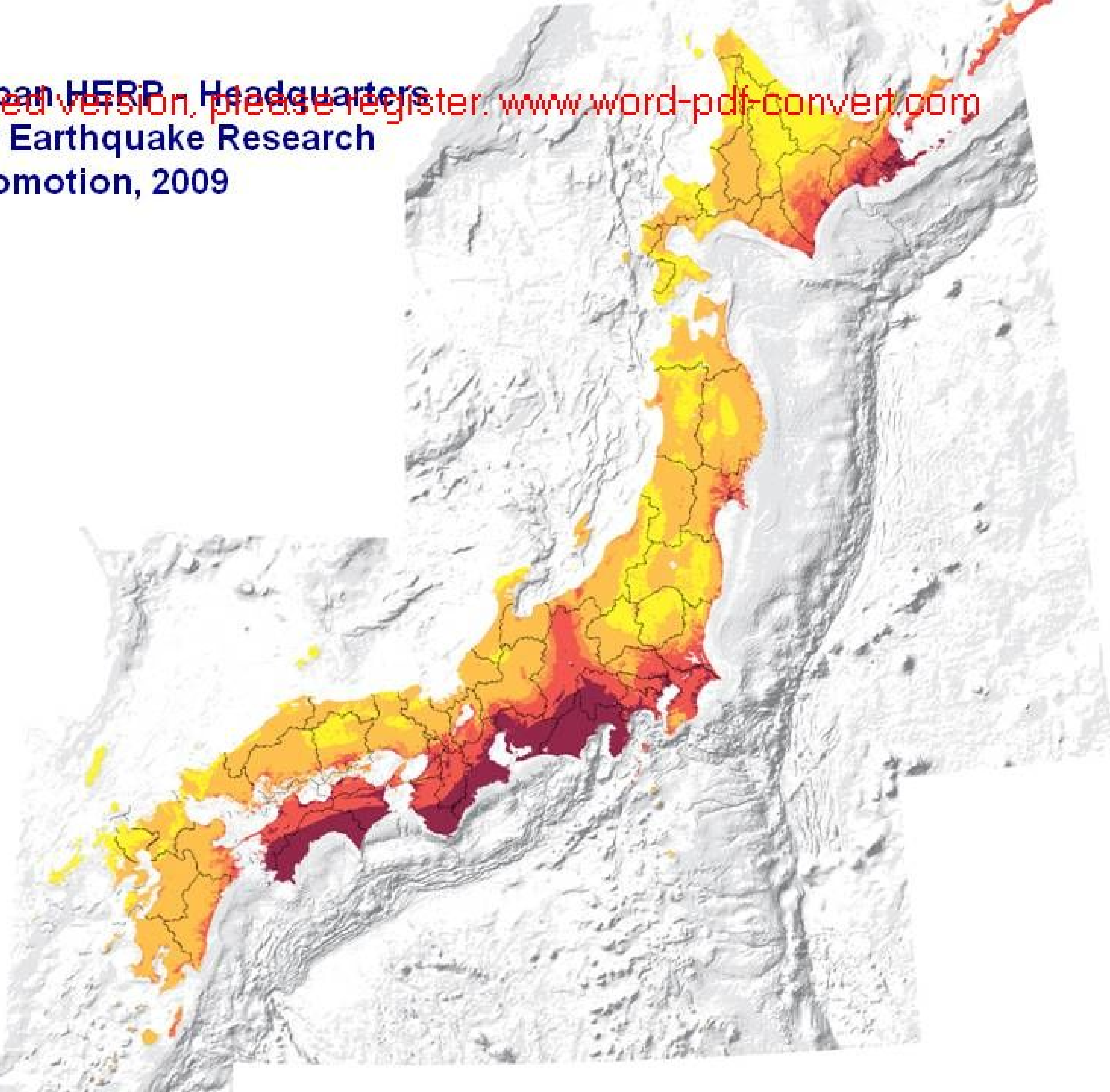
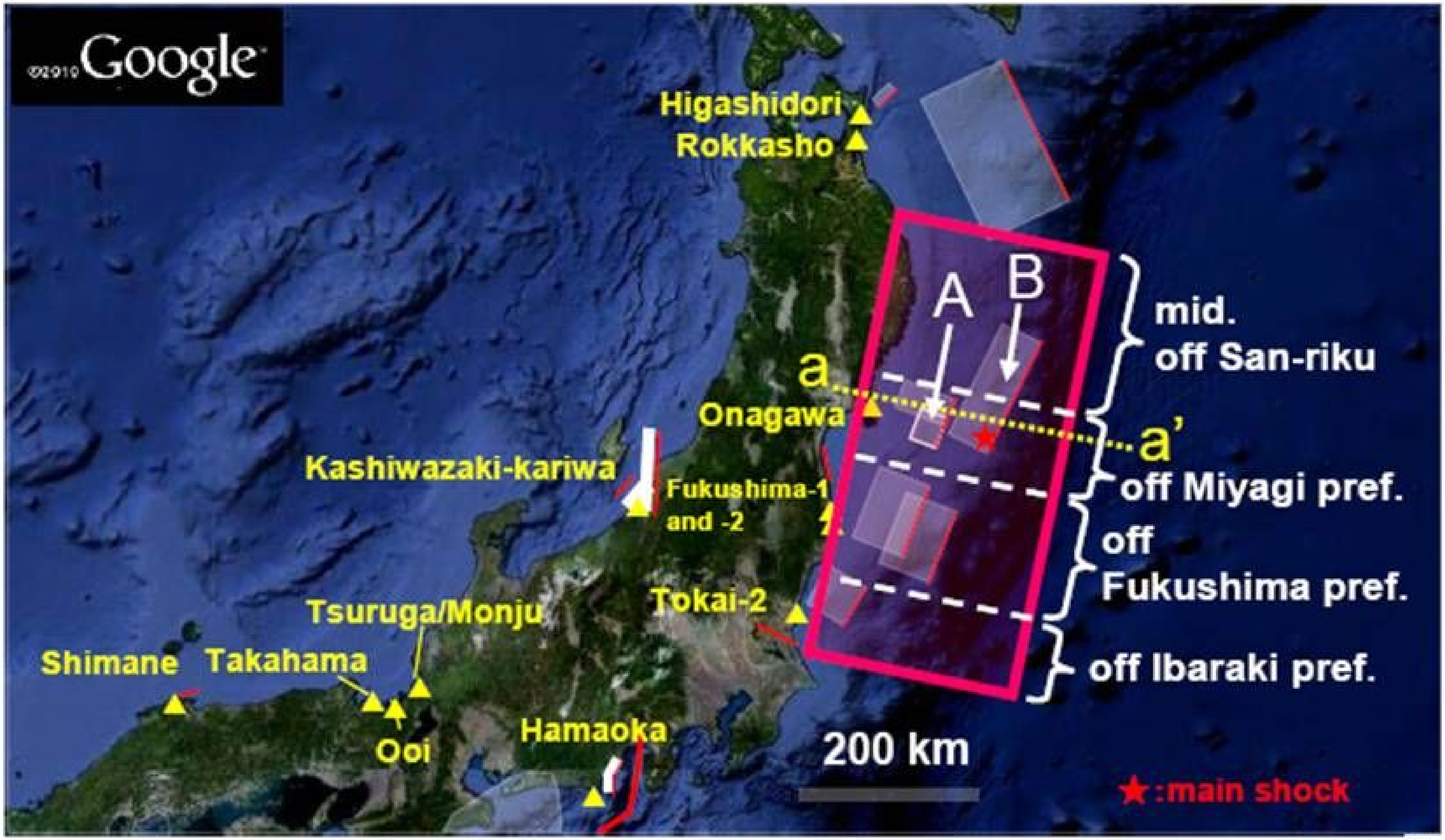
Japan HERP - Headquarters for Earthquake Research Promotion, 2009





JNES modified a part of the Google map.

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活断層・古地震研究報告，No. 7, p. 47-80, 2007

ハンディジオスライサーを用いた宮城県仙台平野（仙台市・名取市・岩沼市・亘理町・山元町）における古津波痕跡調査

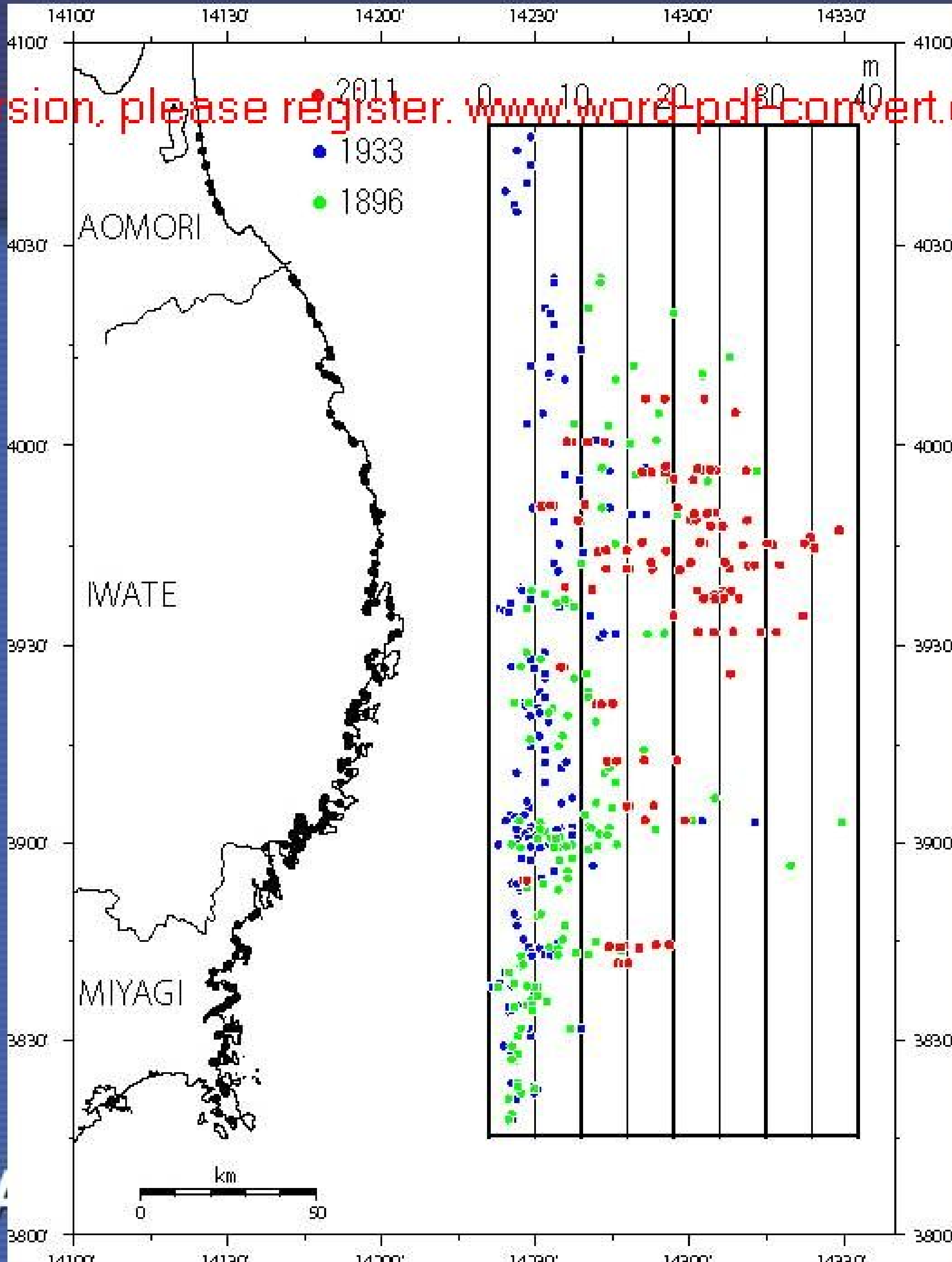
A study on paleotsunami using handy geoslicer in Sendai Plain (Sendai, Natori, Iwanuma, Watari, and Yamamoto), Miyagi, Japan

澤井祐紀[1]・宍倉正展[2]・岡村行信[3]・高田圭太[4]・松浦旅人[5]・Than Tin Aung[6]・小松原純子[7]
藤井雄士郎[8]・藤原　治[9]・佐竹健治[10]・鎌滝孝信[11]・佐藤伸枝[12]

Yuki Sawai[1], Masanobu Shishikura[2], Yukinobu Okamura[3], Keita Takada[4], Tabito Matsu'ura[5], Than Tin Aung[6], Junko Komatsubara[7], Yushiro Fujii[8], Osamu Fujiwara[9], Kenji Satake[10], Takanobu Kamataki[11] and Nobue Sato[12]

[1,2,3,5,6,9,10,12] 活断層研究センター（Active Fault Research Center, GSJ/AIST）
[4] 復建調査設計株式会社（Fukken CO., LTD）
[7] 地質情報研究部門（Institute of Geology and Geoinformation, GSJ/AIST）
[8] 独立行政法人建築研究所（Building Research Institute）
[11] 応用地質株式会社（OYO Corporation）

Abstract: We studied paleotsunami in Sendai Plain (Sendai, Natori, Iwanuma, Watari, and Yamamoto). The study was based on forty-nine sliced samples taken from rice paddies (swales) and beach ridges using the handy geoslicers. The deposits consist mainly of massive (sometimes laminated), poorly-sorted



2011
1933
1896
m
0 10 20 30 40
AOMORI
IWATE
MIYAGI
km
0 50
141°00' 141°30' 142°00' 142°30' 143°00' 143°30'
41°00' 40°30' 40°00' 39°30' 39°00' 38°30' 38°00'

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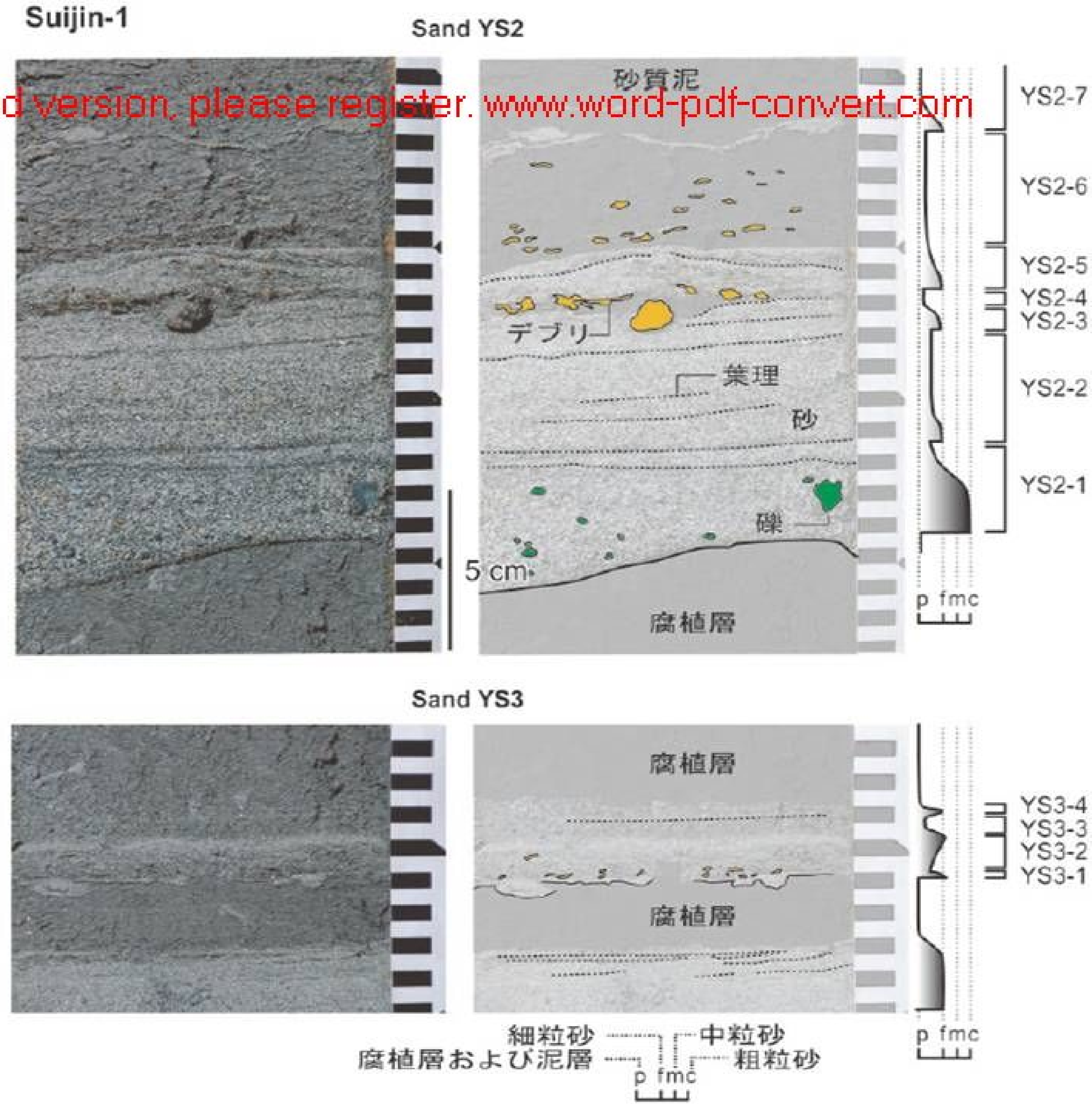
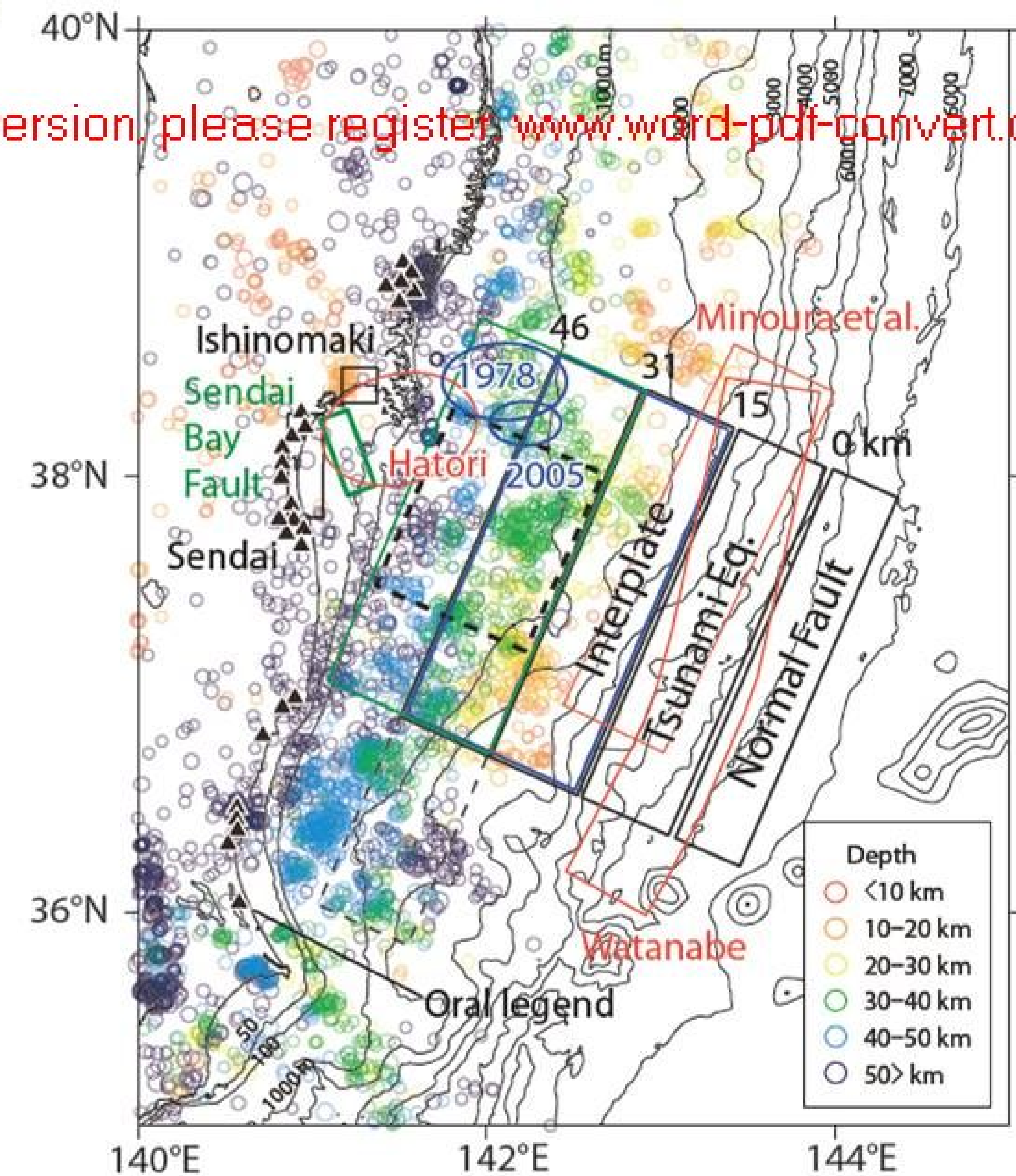
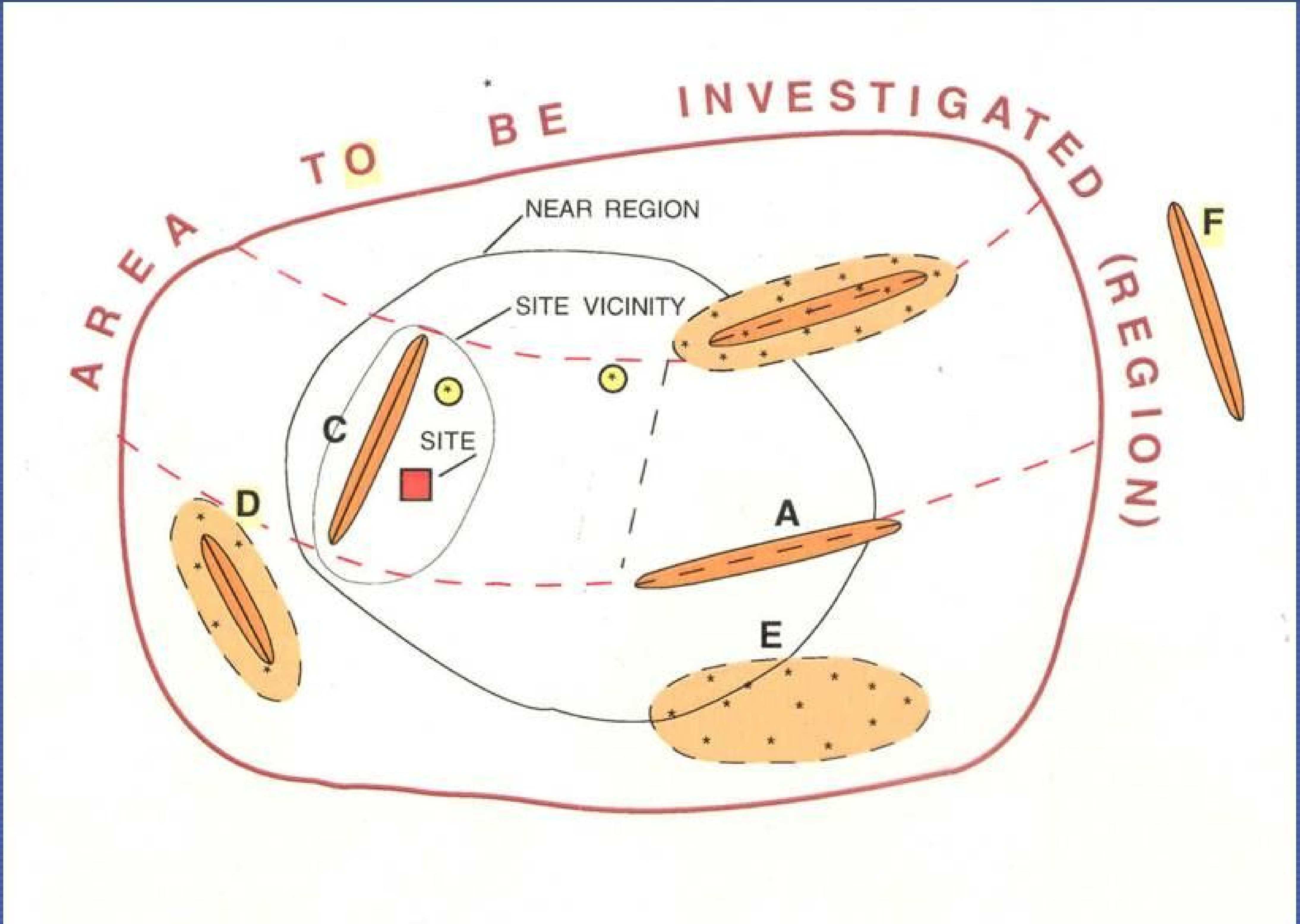

Suijin-1
Sand YS2
砂質泥
デブリ
葉理
砂
礫
5 cm
腐植層
YS2-7
YS2-6
YS2-5
YS2-4
YS2-3
YS2-2
YS2-1
p fmc
Sand YS3
腐植層
腐植層
YS3-4
YS3-3
YS3-2
YS3-1
p fmc
細粒砂
中粒砂
腐植層および泥層
粗粒砂
p fmc



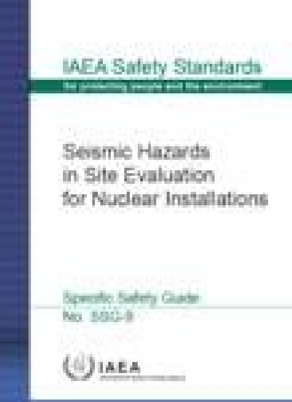
第1図. 貞観津波の断層モデル. 本研究で検討するのは, 正断層モデル, 津波地震モデル, 断層幅 50 km のプレート間地震モデル（黒実線）のほか, プレート間地震の断層の長さを 300 km, 100 km に変えたもの（黒破線）, 幅を 100 km に変えたもの（青, 緑）及び仙台湾の活断層（深緑）. これらのほか, 羽鳥 (1998), Minoura *et al*. (2001), 渡邊 (2000) による推定波源域, 1978 年, 2005 年の宮城県沖地震の震源域も示す. カラーの小

Satake et al., 2008

Necessary information and investigations (database)



Necessary information and investigations (database)



3.4. The compilation of the seismological database will normally be less dependent on the regional, near regional and site vicinity scales than the other databases. However, seismogenic structures in the near region and in the site vicinity will usually be more important for seismic hazard evaluation, depending on the rates of activity, the expected maximum potential magnitudes and the regional attenuation of ground motion. Particularly for some intraplate tectonic settings, attention should be paid to compiling seismological data for more distant seismic sources that may be beyond the typical boundaries of the region. In offshore regions, adequate investigations should be conducted in order to fully analyse the tectonic characteristics of the region and to compensate for any lack of or deficiency in the seismological data.

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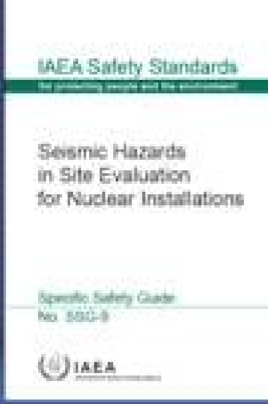
Necessary information and investigations (database)


IAEA Safety Standards

Seismic Hazards in Site Evaluation for Nuclear Installations

Specific Safety Guide No. SSG-9

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3.5. When a seismic hazard analysis is performed for any reason during the operating lifetime of the nuclear installation (e.g. for a periodic safety review or a probabilistic seismic hazard analysis for seismic probabilistic safety assessment), the integrated database should be updated to cover the elapsed time from the most recent compilation of data until the present, and recent scientific findings should be incorporated.

The KK case and the FB fault…..

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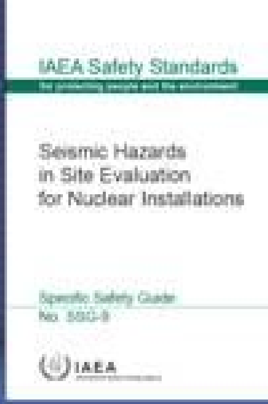
Geological, geophysical and geotechnical database

REGIONAL INVESTIGATIONS

3.8 The purpose of obtaining data on a regional scale is to provide knowledge of the general geodynamic setting of the region and to identify and characterize those geological features that may influence or relate to the seismic hazard at the site.

The most relevant among those geological features are structures that show potential for displacement and/or deformation at or near the ground surface; that is, capable faults.

Geological, geophysical and geotechnical database

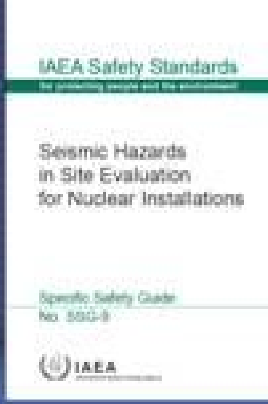


DATA COLLECTION

The data obtained from any type of published and unpublished geological and geophysical sources (for example, data derived from existing galleries, road cuts or water boreholes) and should be presented on maps with appropriate cross-sections.

The size of the relevant region will vary depending on the geological and tectonic setting, and its shape may be asymmetric in order to include distant significant sources of earthquakes. Its radial extent will typically be 300 km or more.

Geological, geophysical and geotechnical database



NEW GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS

3.9 Where existing data are inadequate for the purpose of delineating seismogenic structures, in terms of location, extent and rate of ongoing tectonism, it may be necessary to verify and complete the database by acquiring new geological and geophysical data.

This may involve investigations at the scale (detail) of the near region and site vicinity to assess the potential seismogenic features located outside the near region. Identification of the ground effects of past earthquakes on the geological–geomorphological environment (that is, the **palaeoseismology**; see par. 4.13) is also useful for this purpose. The data are typically presented on maps at a scale of 1:500 000 and with appropriate cross-sections.

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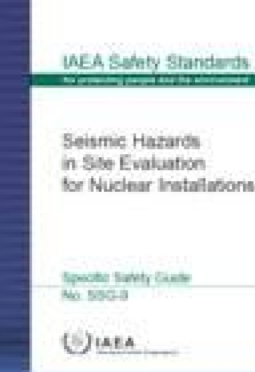
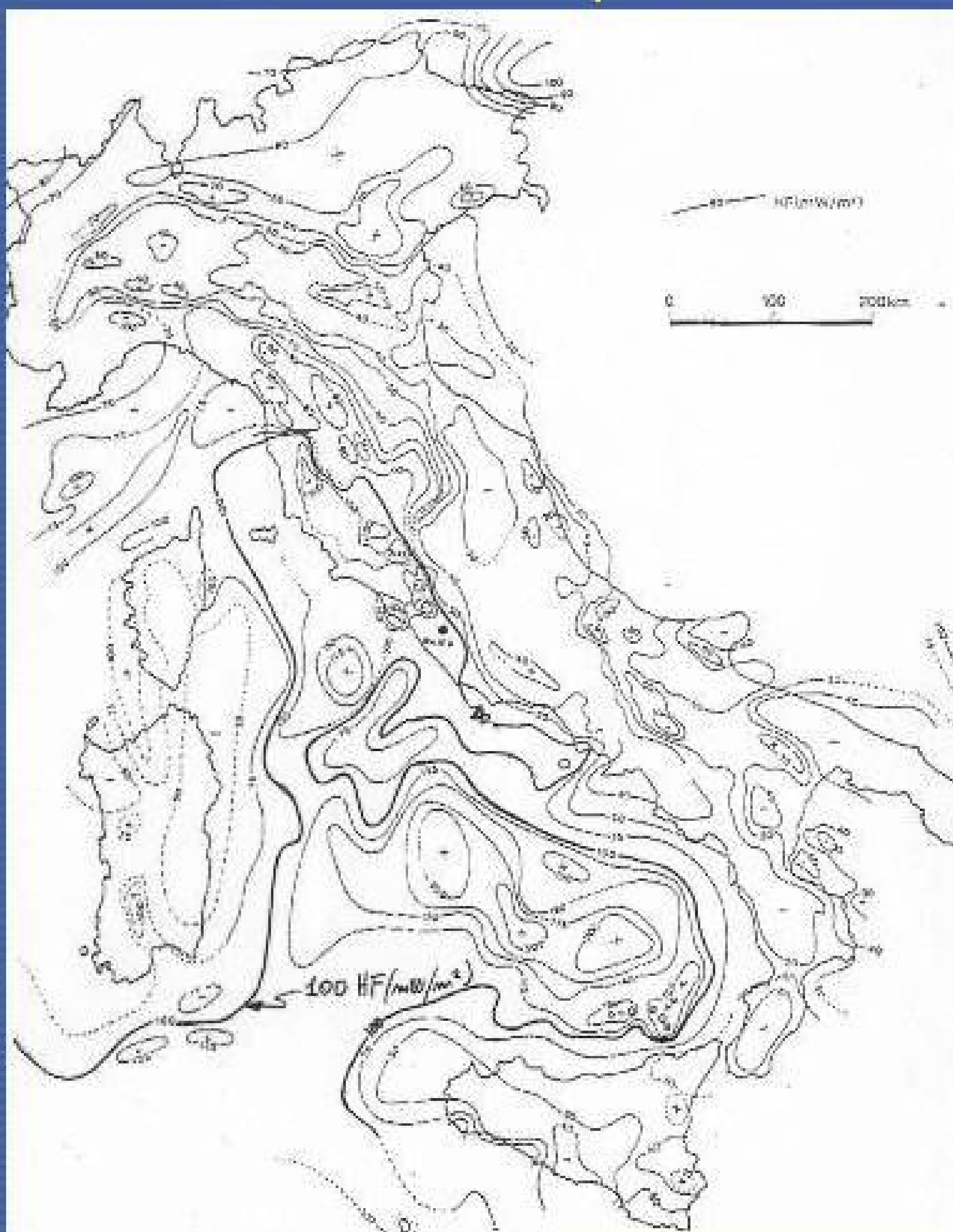
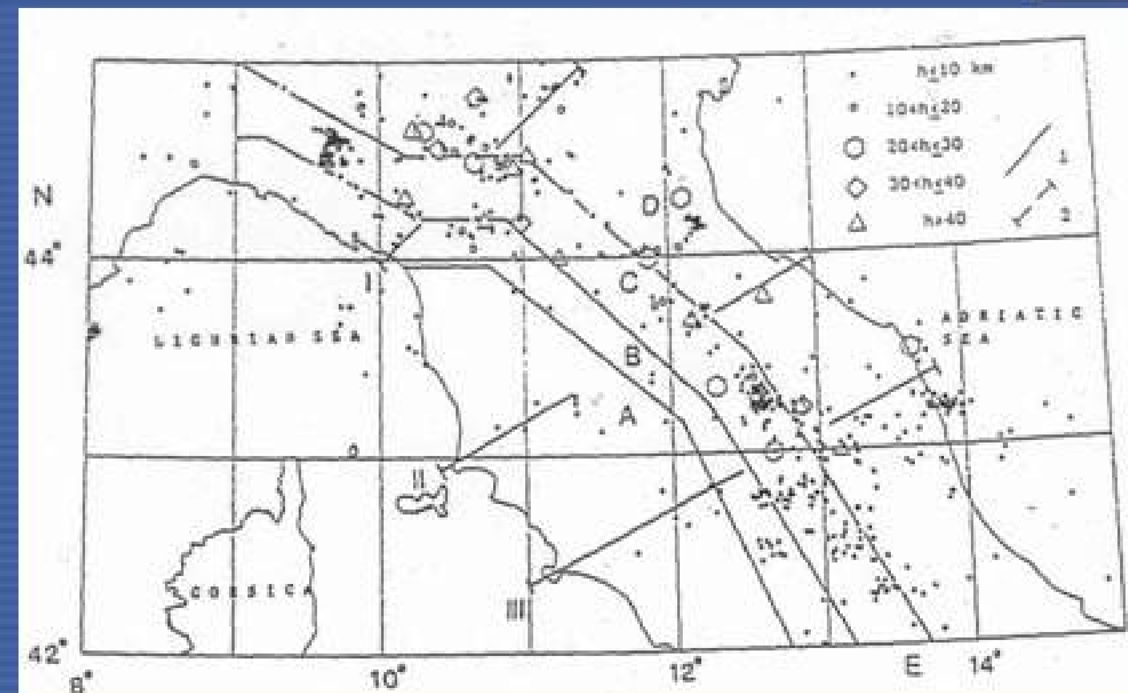
Geological, geophysical and geotechnical database

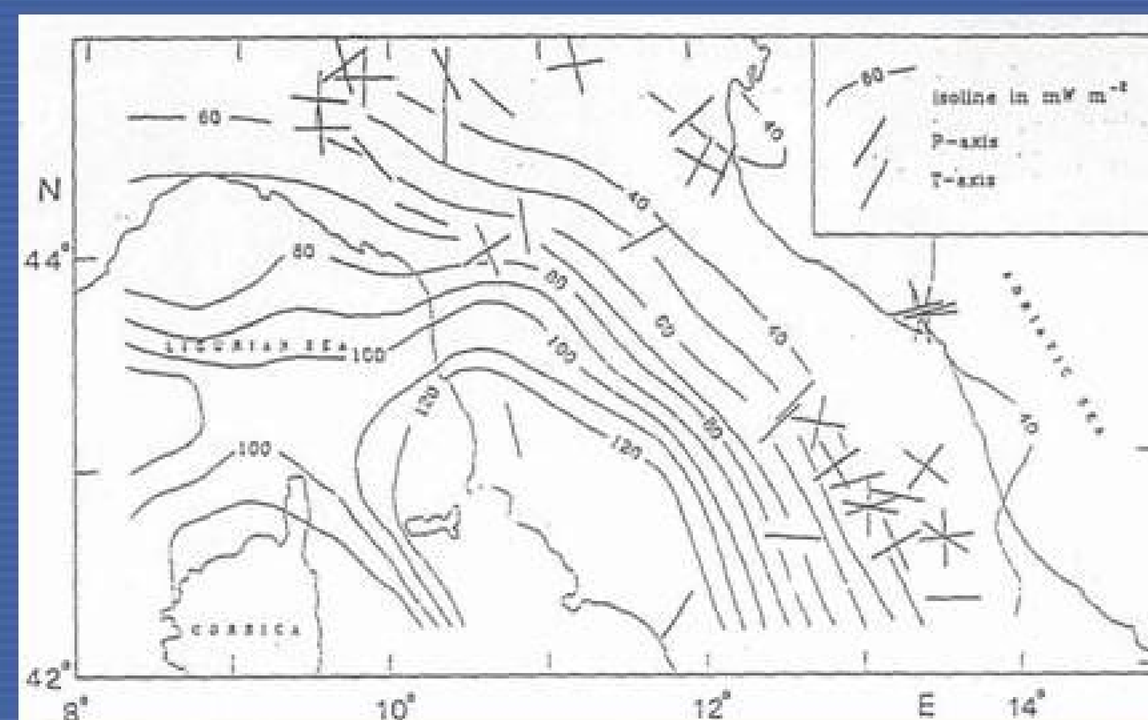


Regional investigations:

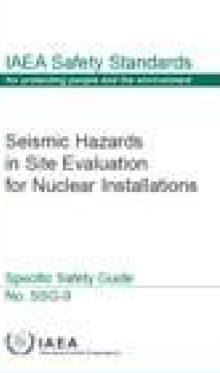
Heat flow and earthquake data







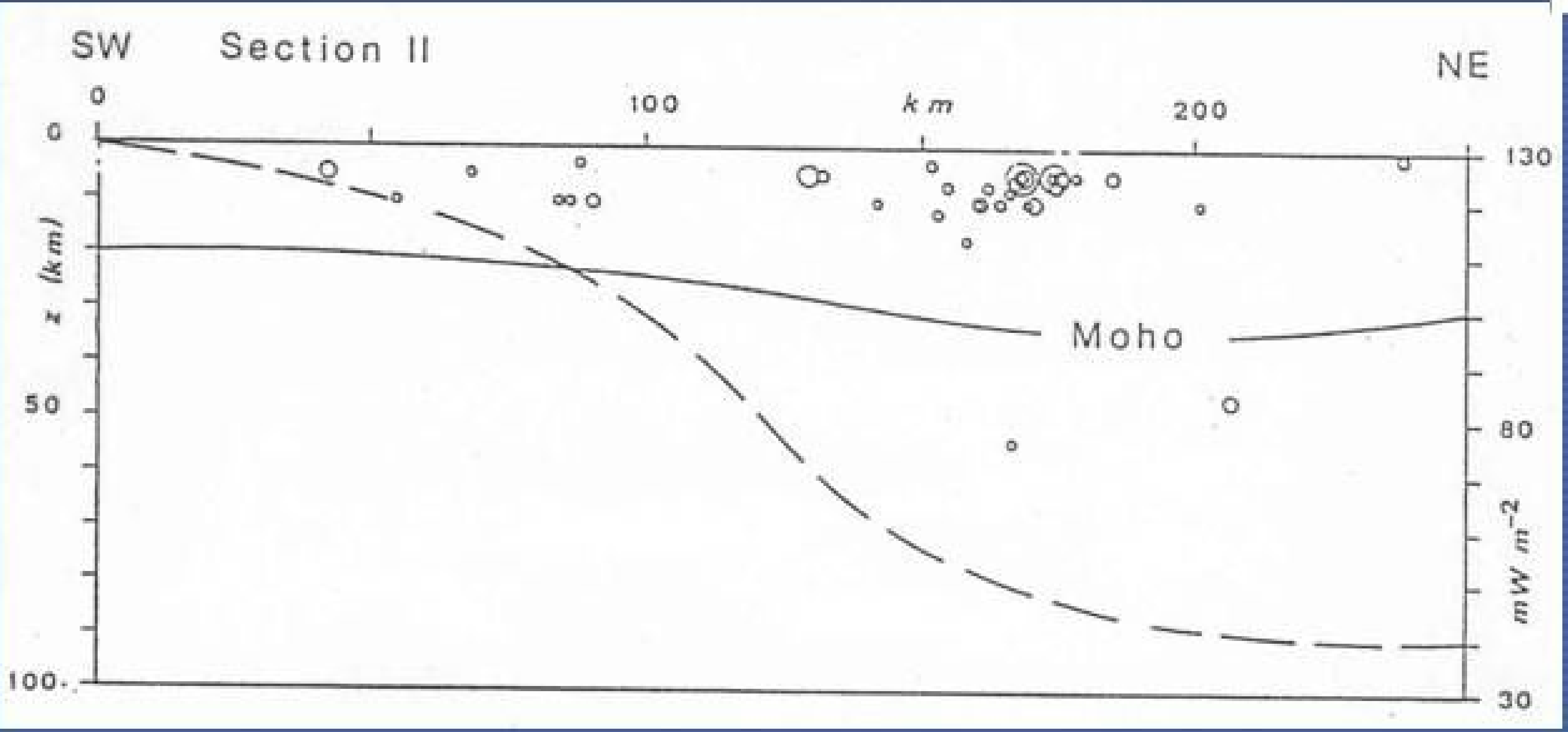
Geological, geophysical and geotechnical database

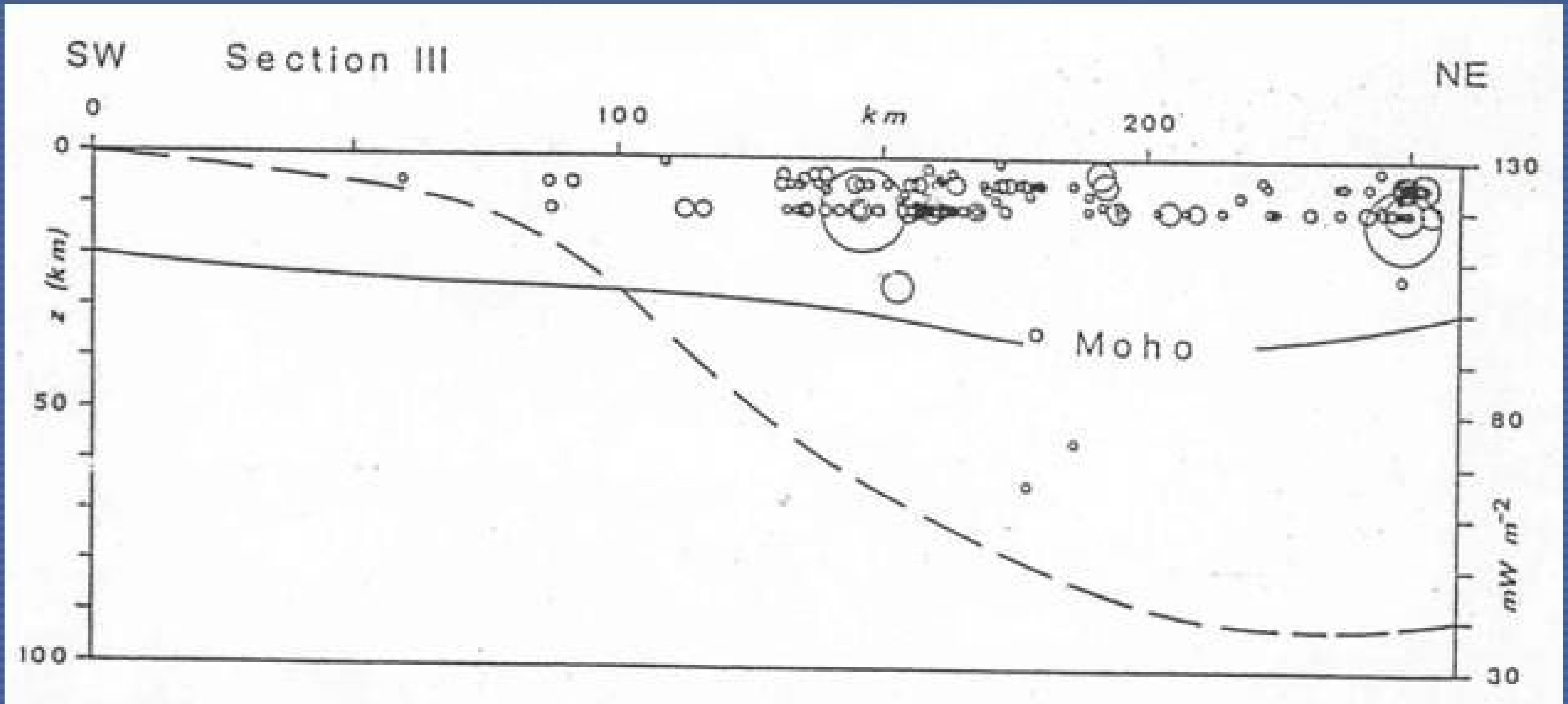


Regional investigations:

Heat flow and earthquake

cross sections





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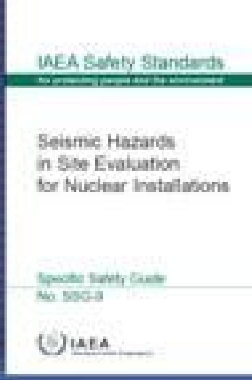
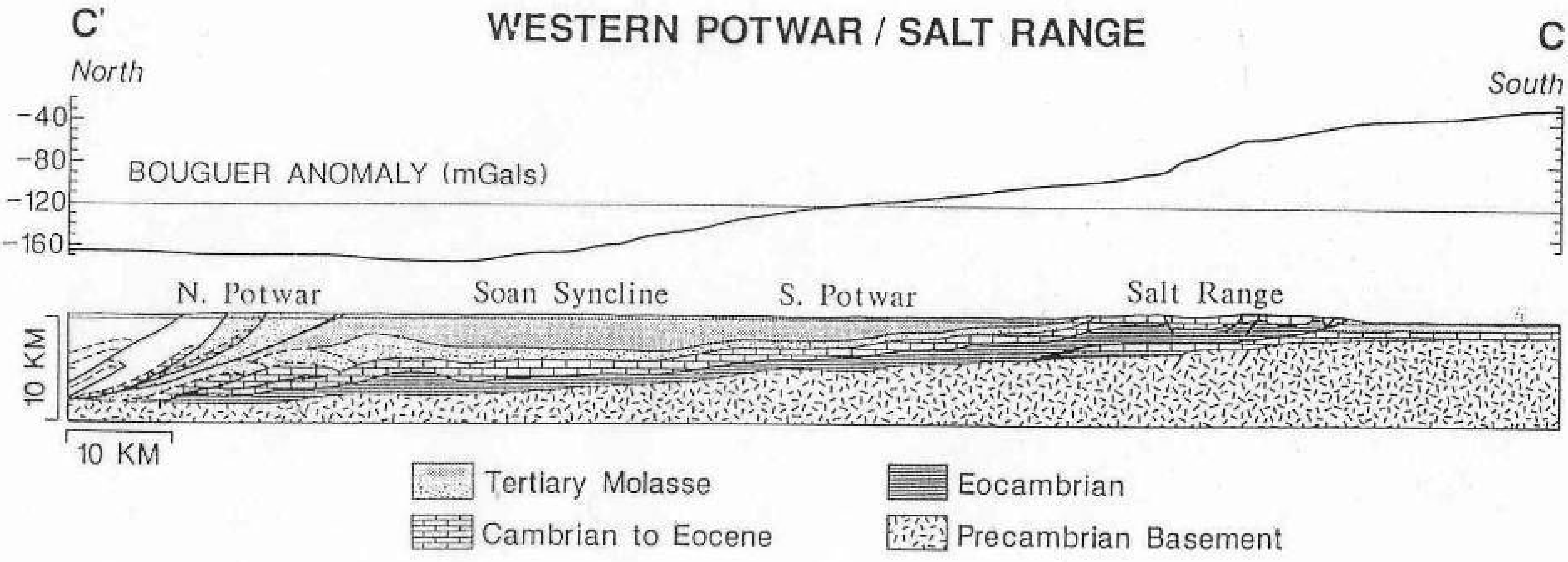
Geological, geophysical and geotechnical database

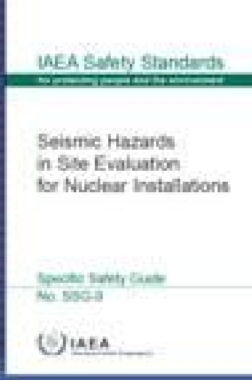


Regional investigations:

Geological and gravimetric cross-sections



Geological, geophysical and geotechnical database



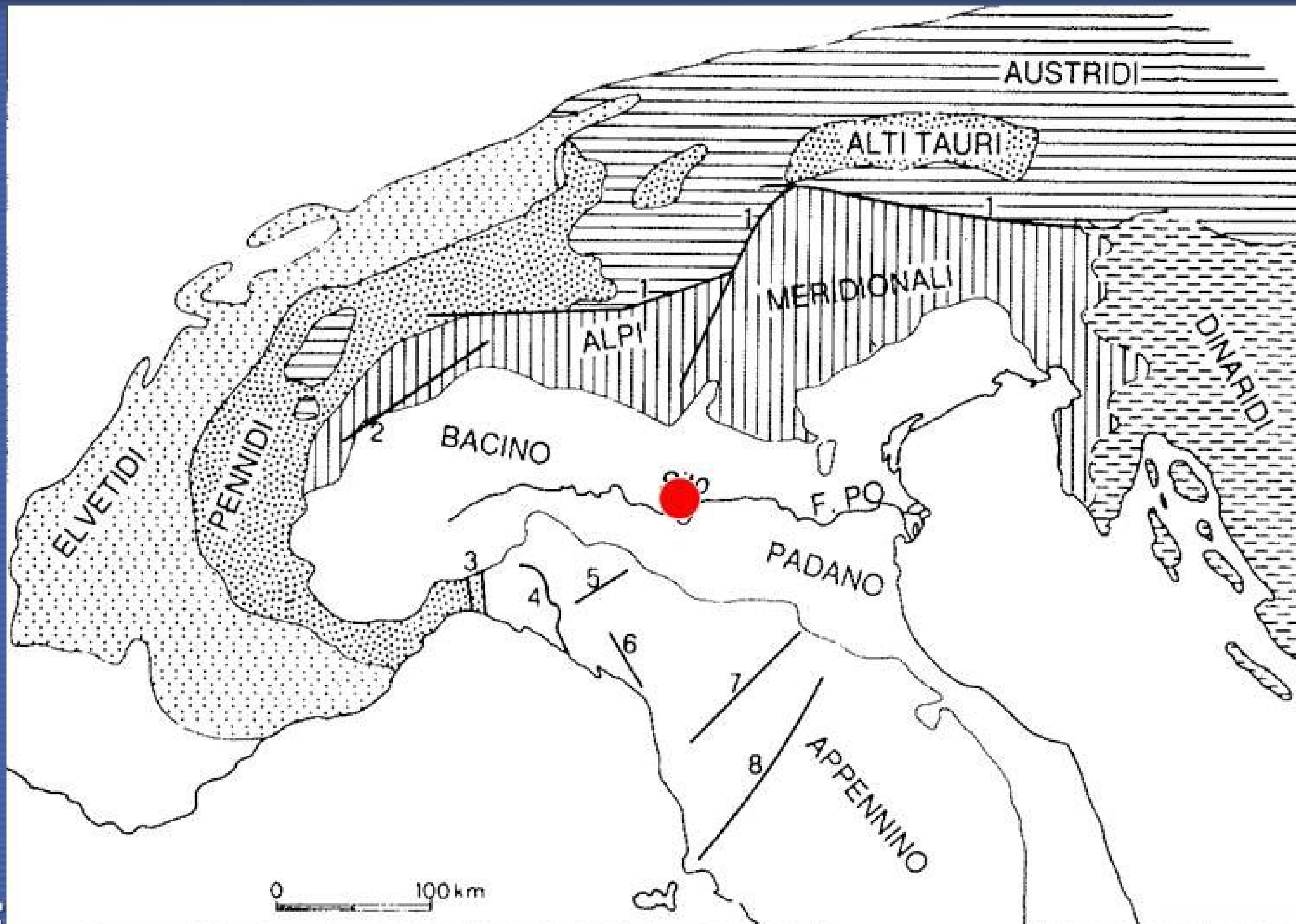
Regional investigations:

Seismic reflection profiles

Geological, geophysical and geotechnical database

Viadana (Northern Italy):

regional investigations



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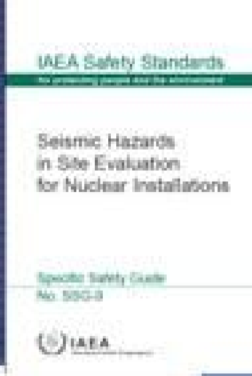
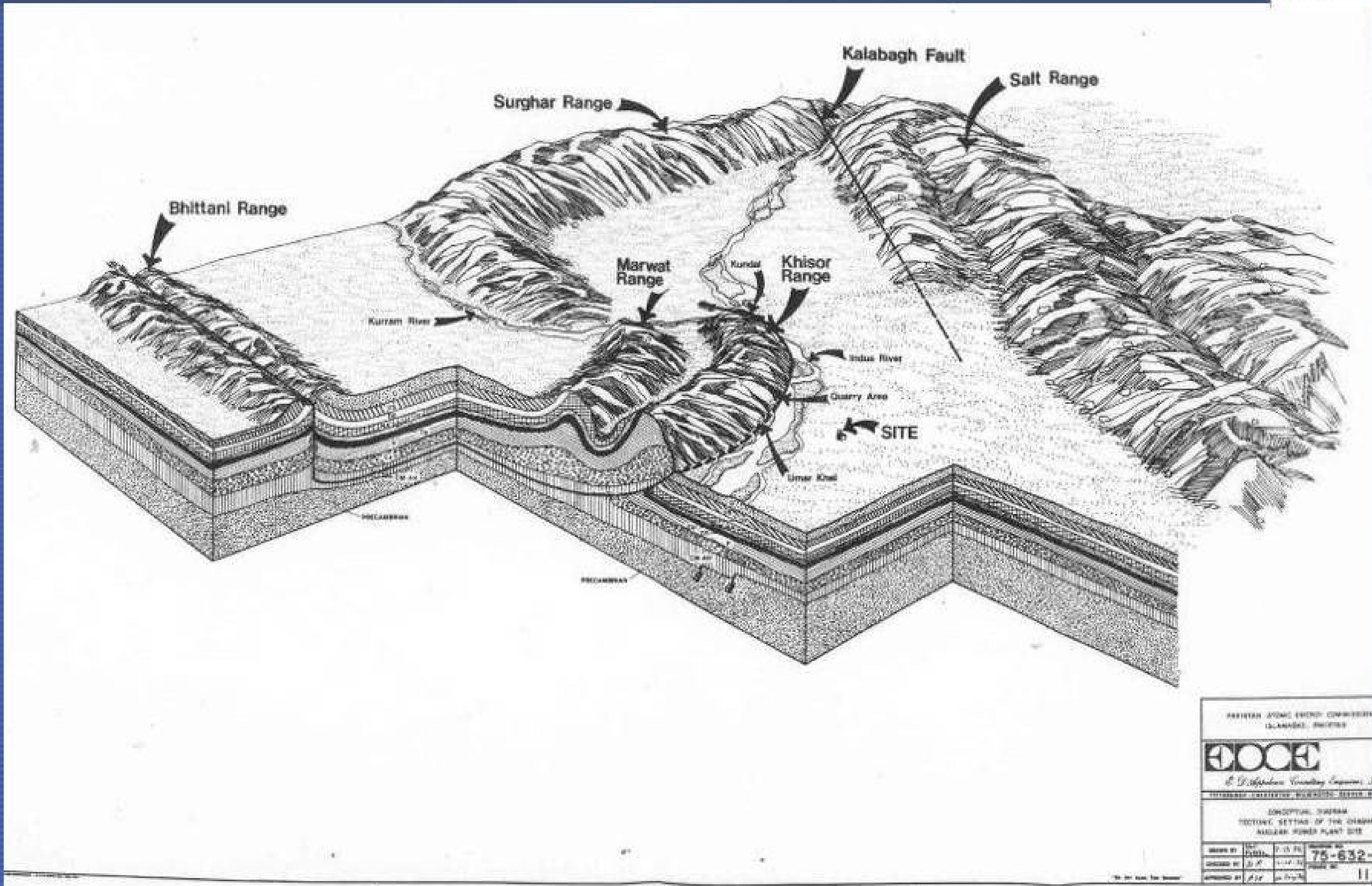
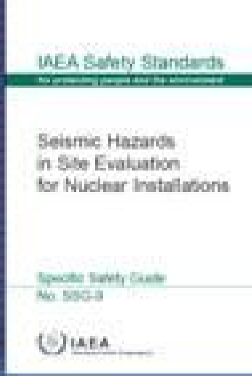
Geological, geophysical and geotechnical database





Geological, geophysical and geotechnical database



NEAR REGIONAL INVESTIGATIONS

3.11 Near regional studies should include a geographical area typically not less than 25 km in radius, although this dimension should be adjusted to reflect local conditions. The objectives are:

- to define the seismotectonic characteristics of the near region on the basis of a more detailed database than that obtained from the regional study;
- to determine the latest movements of faults; and,
- to determine the amount and nature of displacements, rates of activity and evidence of segmentation of faults.

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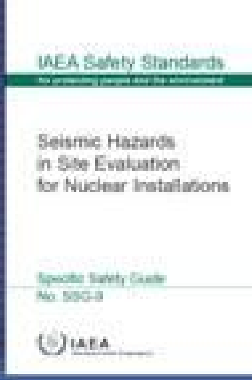
Geological, geophysical and geotechnical database



NEAR REGIONAL: SPECIFIC INVESTIGATIONS

3.12. To supplement the published and unpublished information for the near regional area, specific investigations should typically include a definition of the stratigraphy, structural geology and tectonic history of the near region. The tectonic history should be thoroughly defined for the present tectonic regime, the length of which will depend on the rate of tectonic activity. For example, for studies to assess fault capability, the tectonic information through the Upper Pleistocene–Holocene (i.e. the present) may be adequate for interplate regions and through the Pliocene–Quaternary (i.e. the present) for intraplate regions. Age dating, by any reliable and applicable method, should be performed.

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Geological, geophysical and geotechnical database

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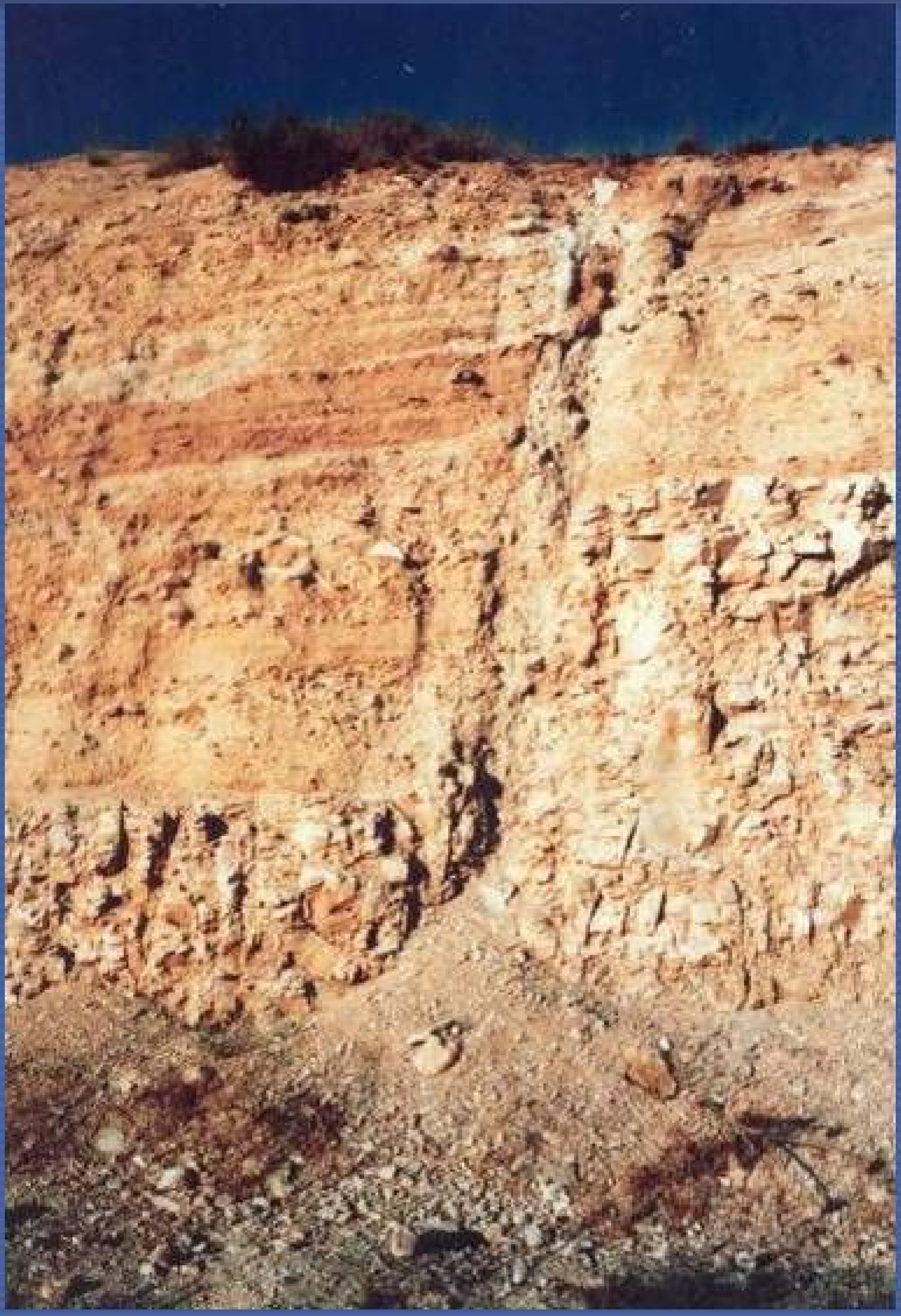
Road cut near the Angra site, Brazil

Geological, geophysical and geotechnical database



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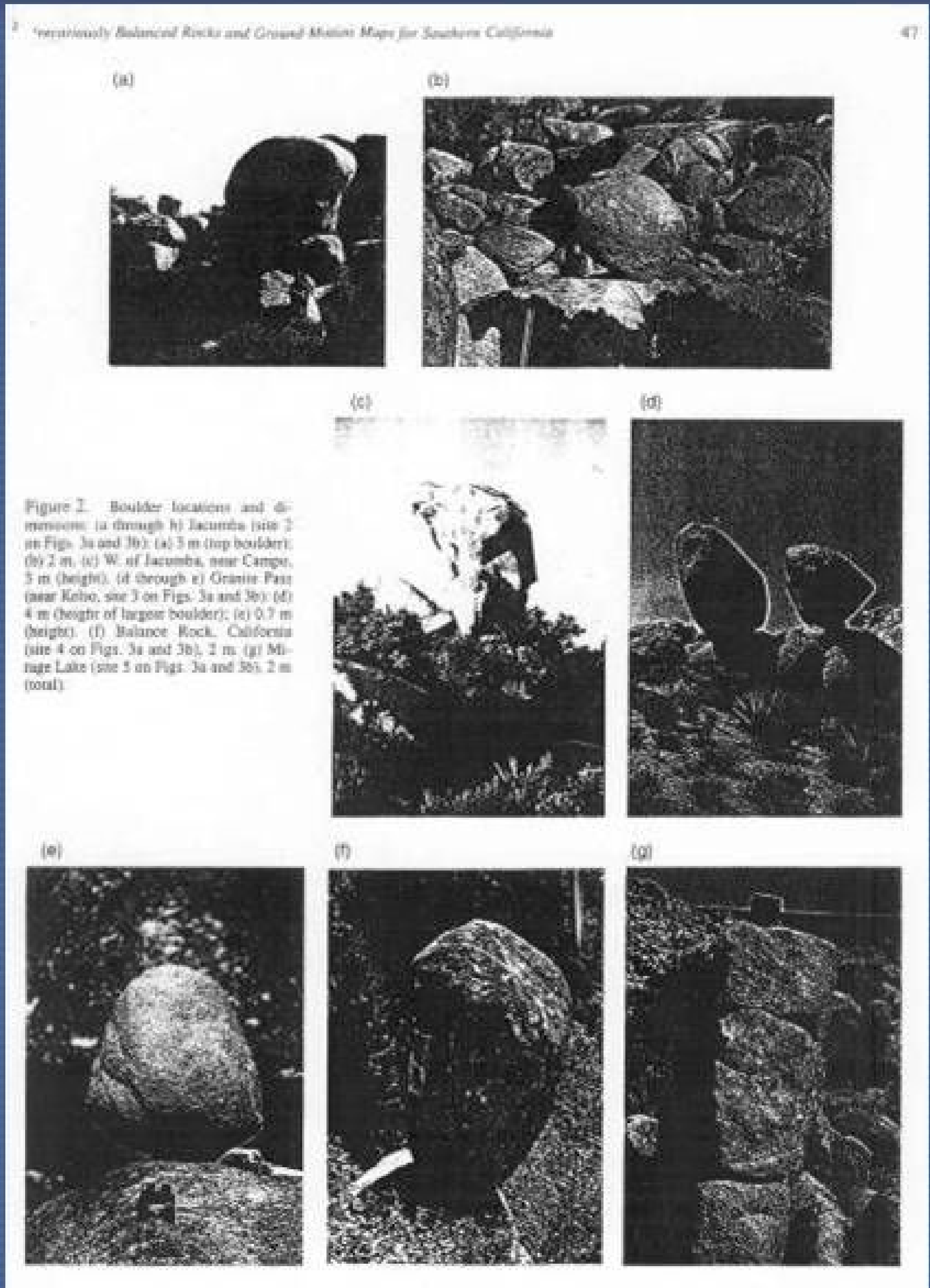
Geological, geophysical and geotechnical database



(a) (b) (c) (d)

Figure 2. Boulder locations and dimensions: (a through h) Jacumba (site 2 on Figs. 3a and 3b): (a) 3 m (top boulder); (b) 2 m. (c) W. of Jacumba, near Campo, 3 m (height). (d through e) Granite Pass (near Kelso, site 3 on Figs. 3a and 3b): (d) 4 m (height of largest boulder); (e) 0.7 m (height). (f) Balance Rock, California (site 4 on Figs. 3a and 3b), 2 m. (g) Mirage Lake (site 5 on Figs. 3a and 3b), 2 m (total).

(e) (f) (g)

Geological, geophysical and geotechnical database – El Dabaa, Egypt

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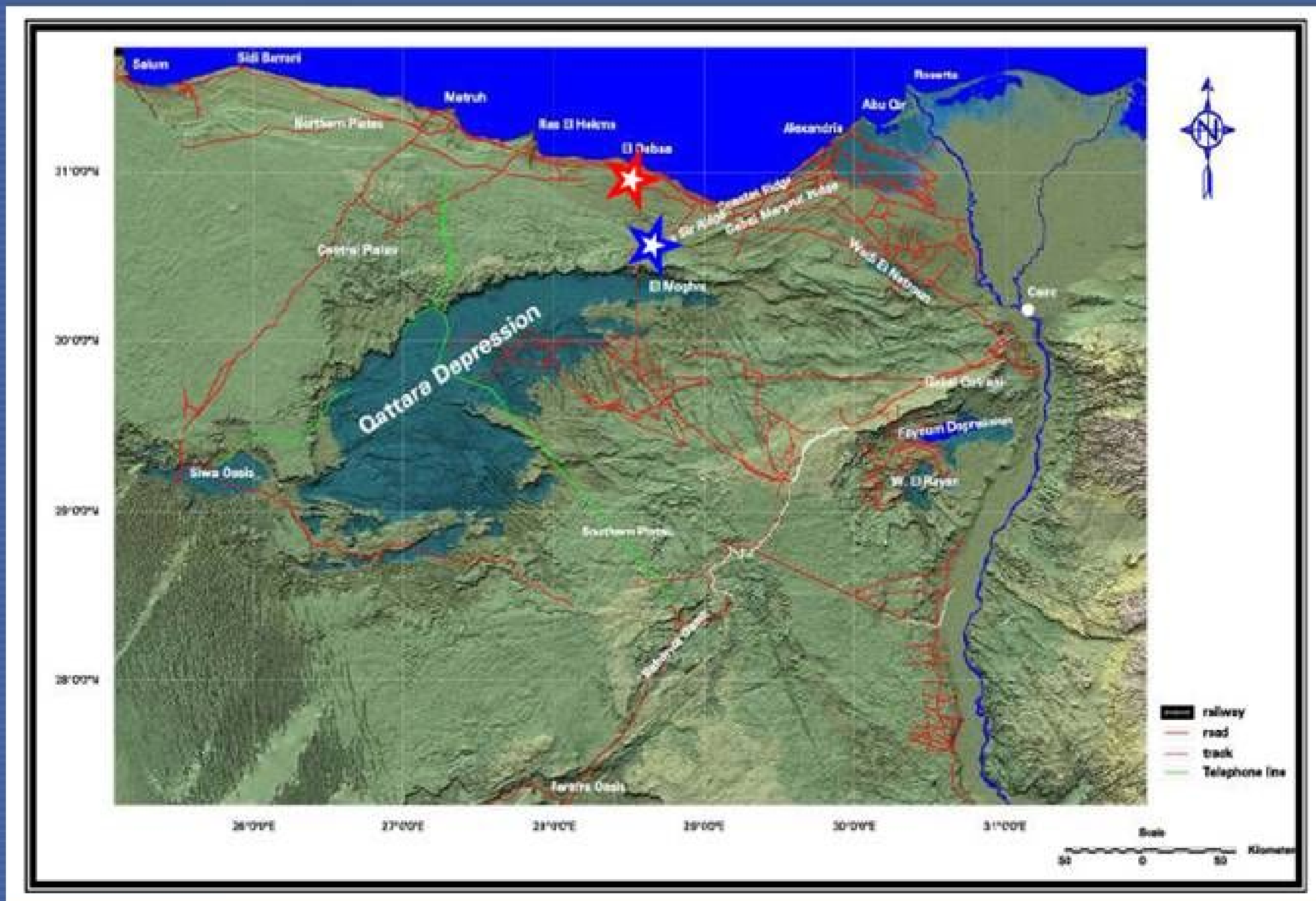
Geological, geophysical and geotechnical database



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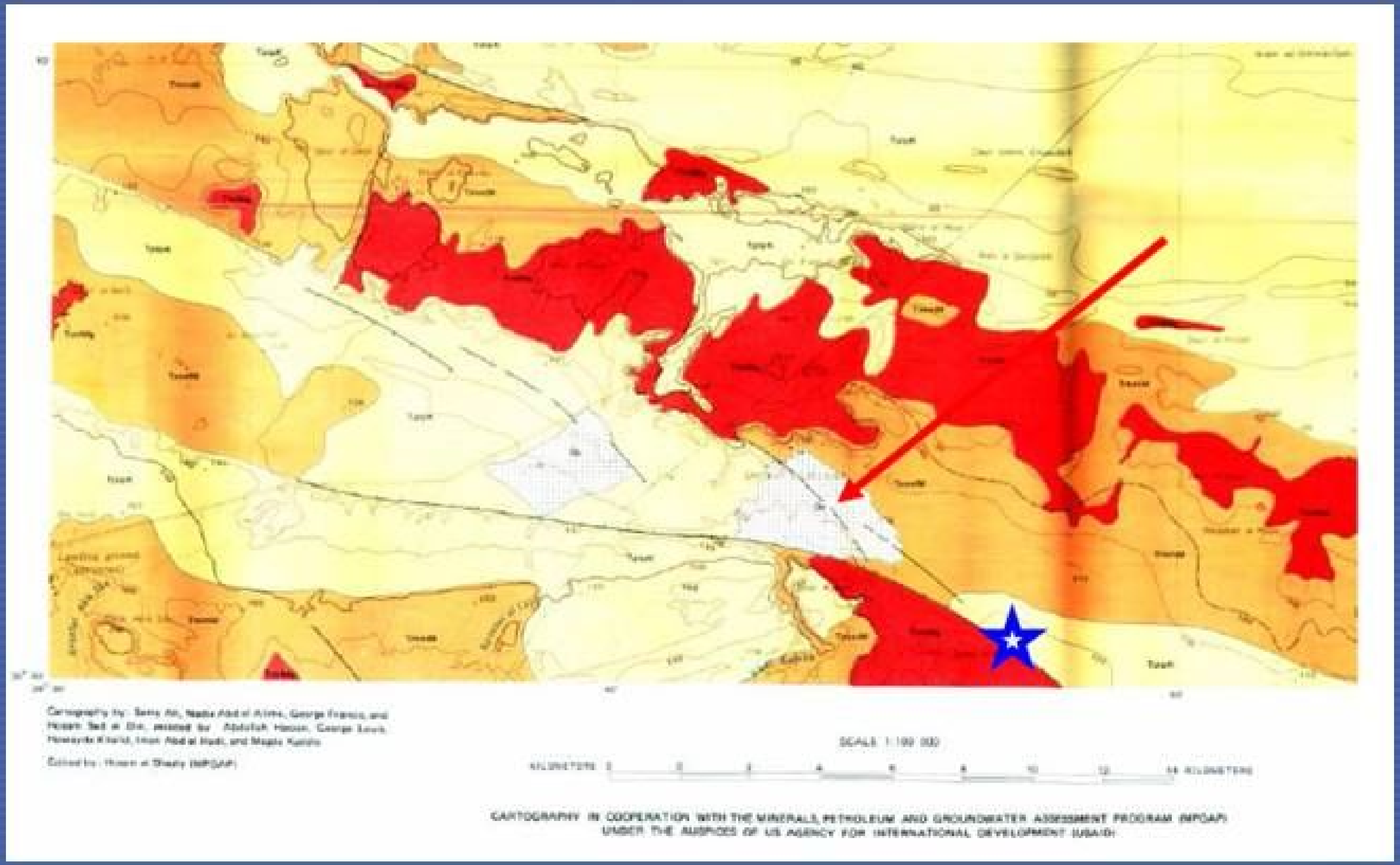
Geological, geophysical and geotechnical database



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Geological, geophysical and geotechnical database

Geological, geophysical and geotechnical database

Geological, geophysical and geotechnical database

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Geological, geophysical and geotechnical database

NEAR REGIONAL: ADDITIONAL INVESTIGATIONS

3.12 In addition to field mapping, various sources of data should be used, for example:

- Subsurface data derived from geophysical investigations (such as seismic reflection and refraction, and gravimetric, electric and magnetic techniques). These data are of primary importance in dealing with offshore areas.
- Surface data derived from studies of Quaternary formations or landforms, such as terrace analysis and pedological and sedimentological studies. Use should be made of aerial and satellite photographs and/or images for this task.
- For understanding the ongoing rate and type of deformation, use should also be made of data derived by recently developed technological means, such as global positioning system data and interferometry data, and data derived from strain rate measurements.

Geological, geophysical and geotechnical database

3.13 For some relevant structures identified in the near regional investigations, it may be necessary to conduct additional studies at the site vicinity scale.

3.14 Investigations should be made in sufficient detail so that the causes of each recent (in terms of the pertinent time window for the specific local tectonic environment) geological and geomorphological feature that is relevant can be properly included in a reasonable model of the recent geological evolution of the area.

3.15 The data are typically presented on maps at a scale of 1:50 000 and with appropriate cross-sections.

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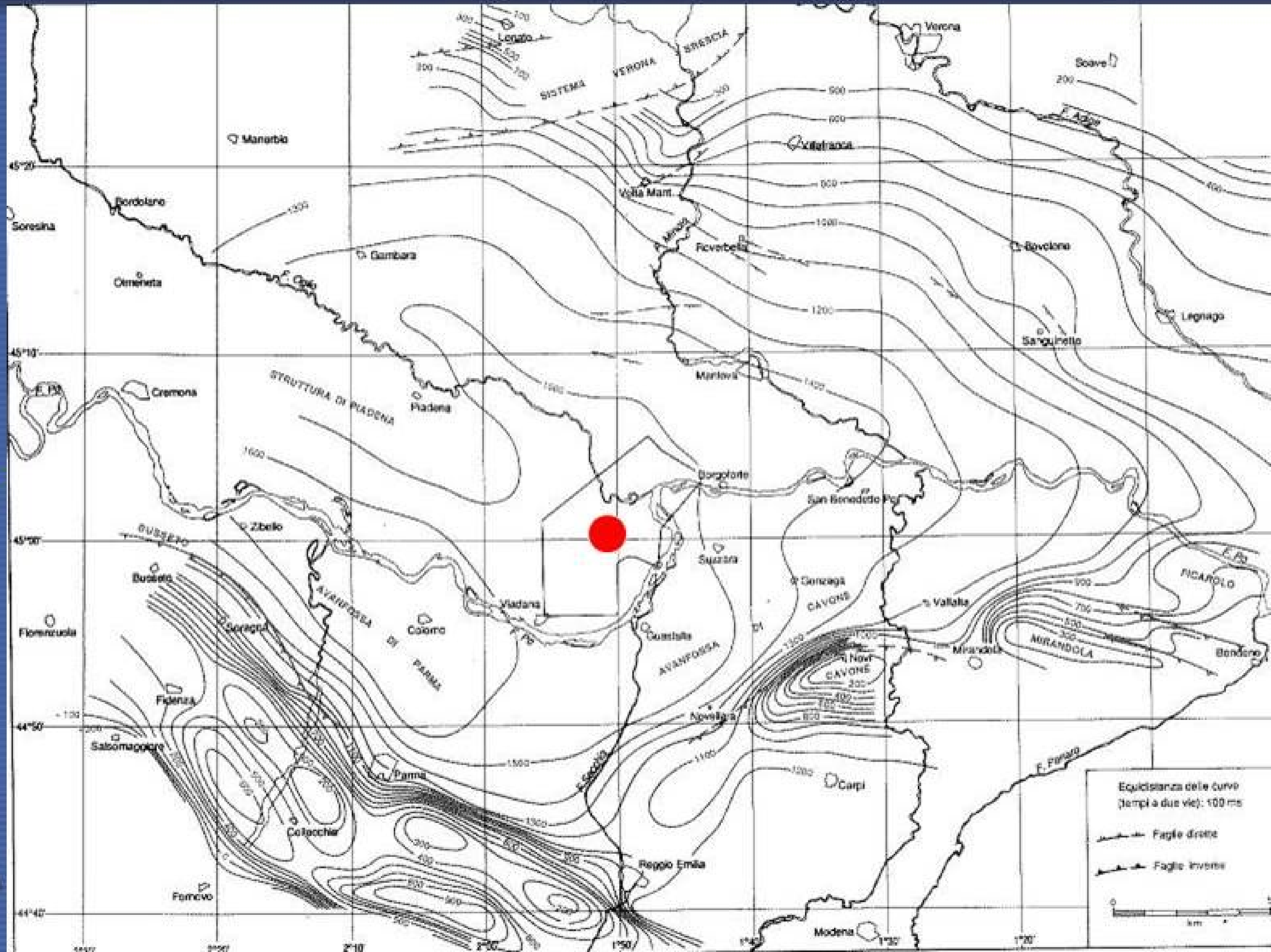
Geological, geophysical and geotechnical database

Viadana (Northern Italy):

near-regional geophysical investigations

BASE of QUATERNARY DEPOSITS



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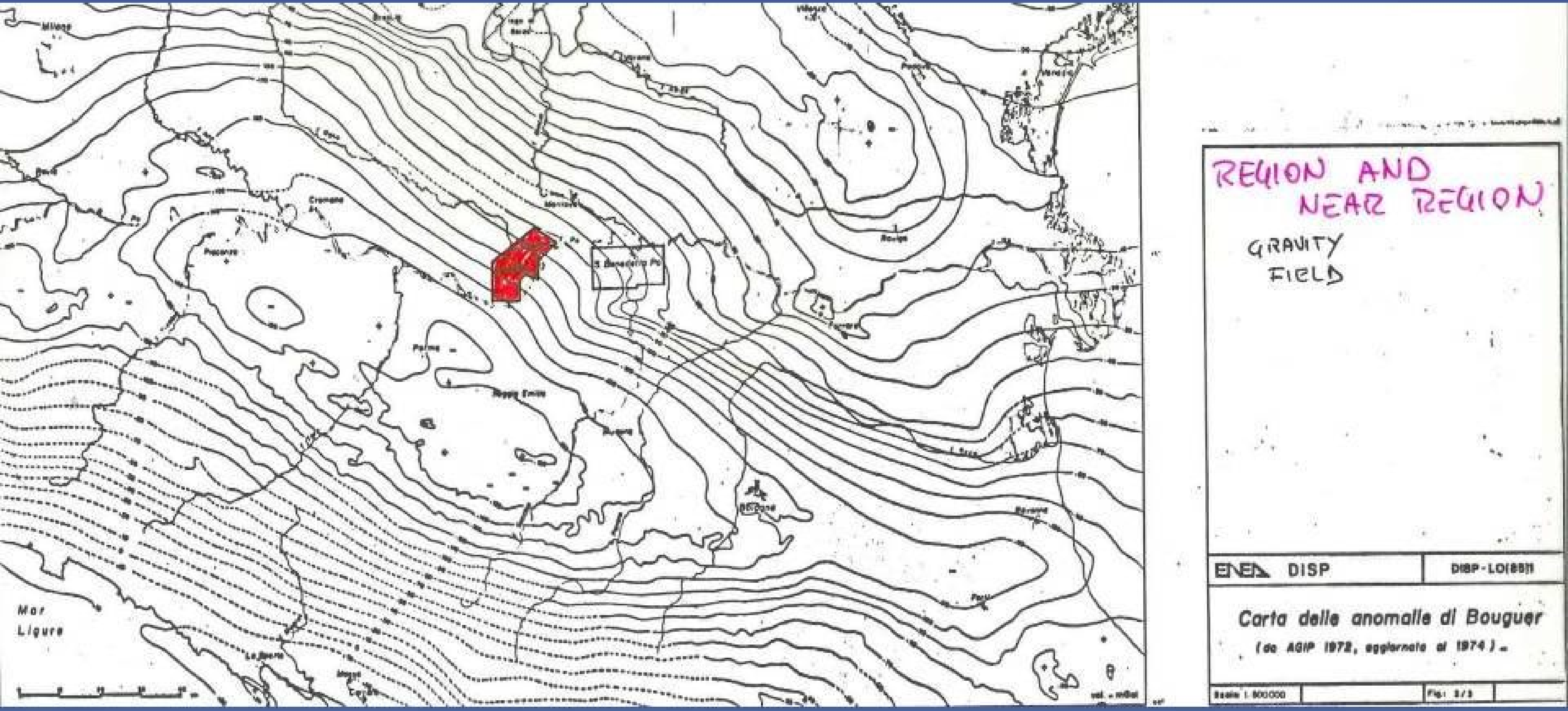
Geological, geophysical and geotechnical database

Near-regional investigations



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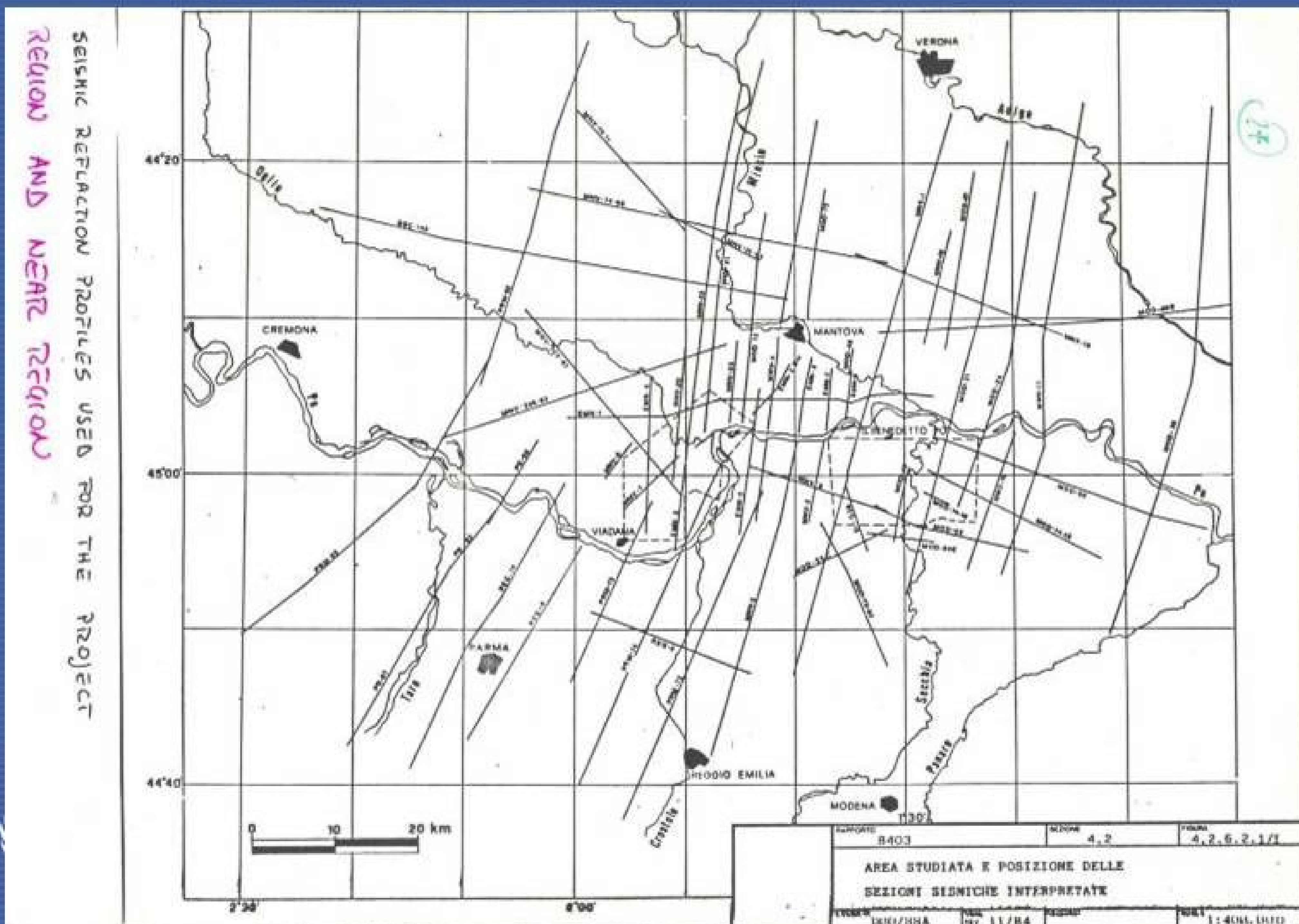
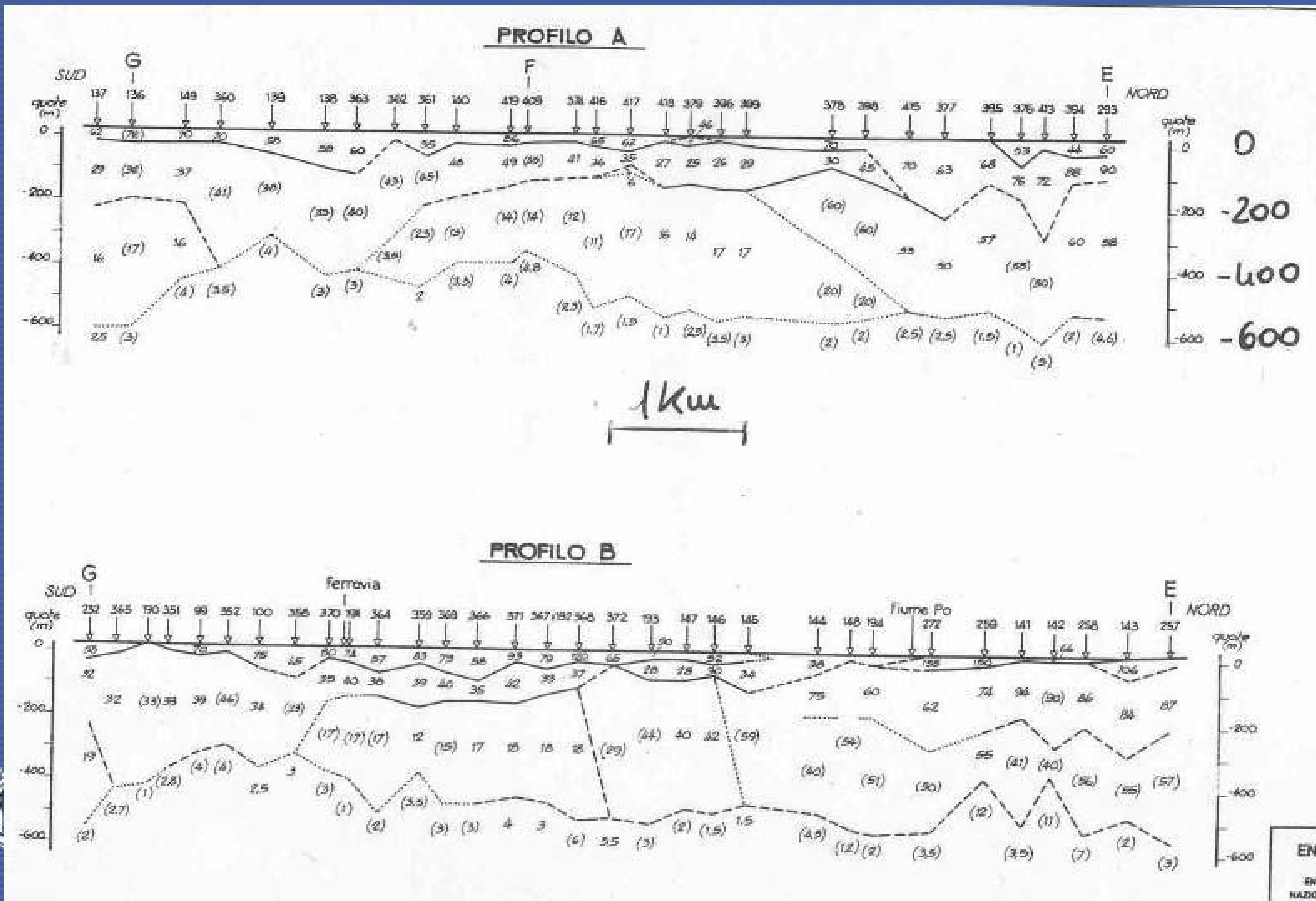
Geological, geophysical and geotechnical database

Near-regional investigations



Geological, geophysical and geotechnical database

Near regional investigations: geoelectrical prospecting

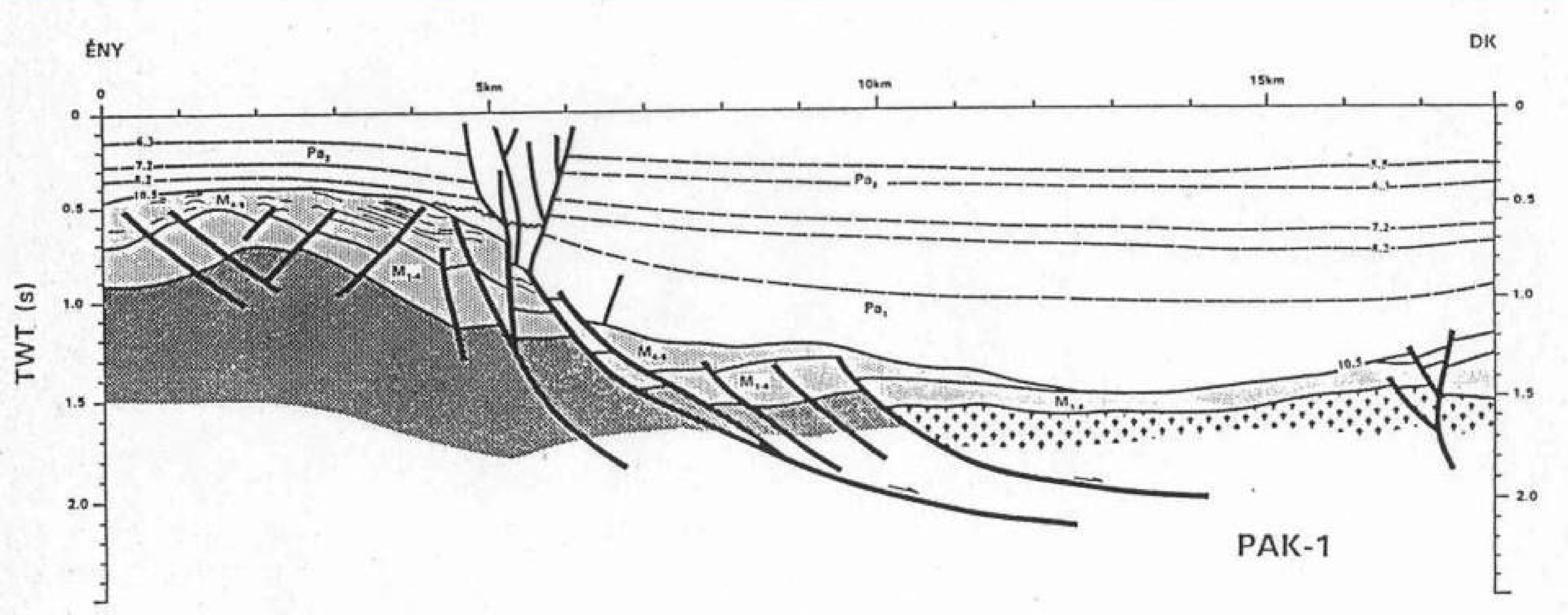


Geological, geophysical and

geotechnical database

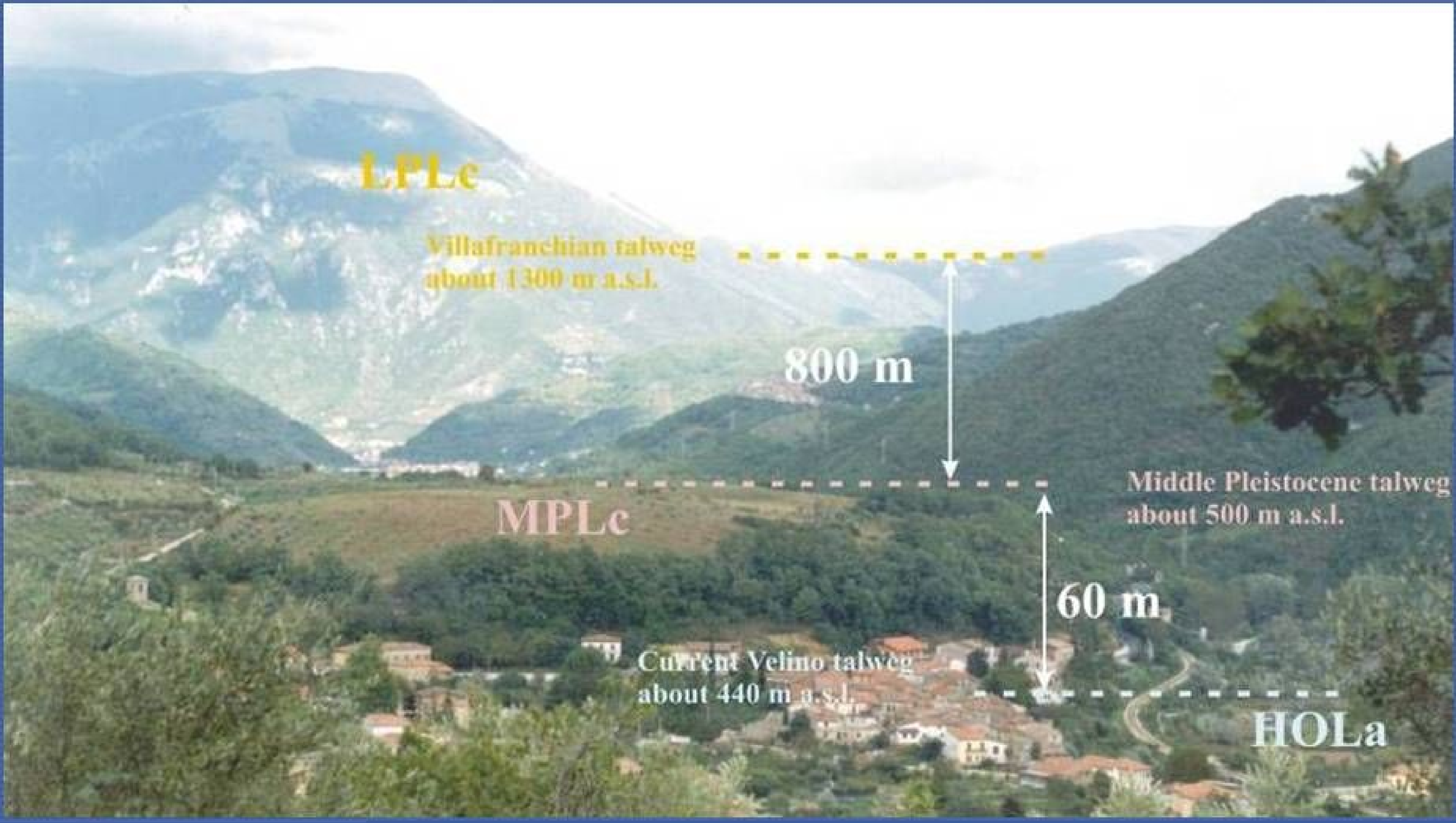
Near-regional investigations:

Seismic reflection profiles



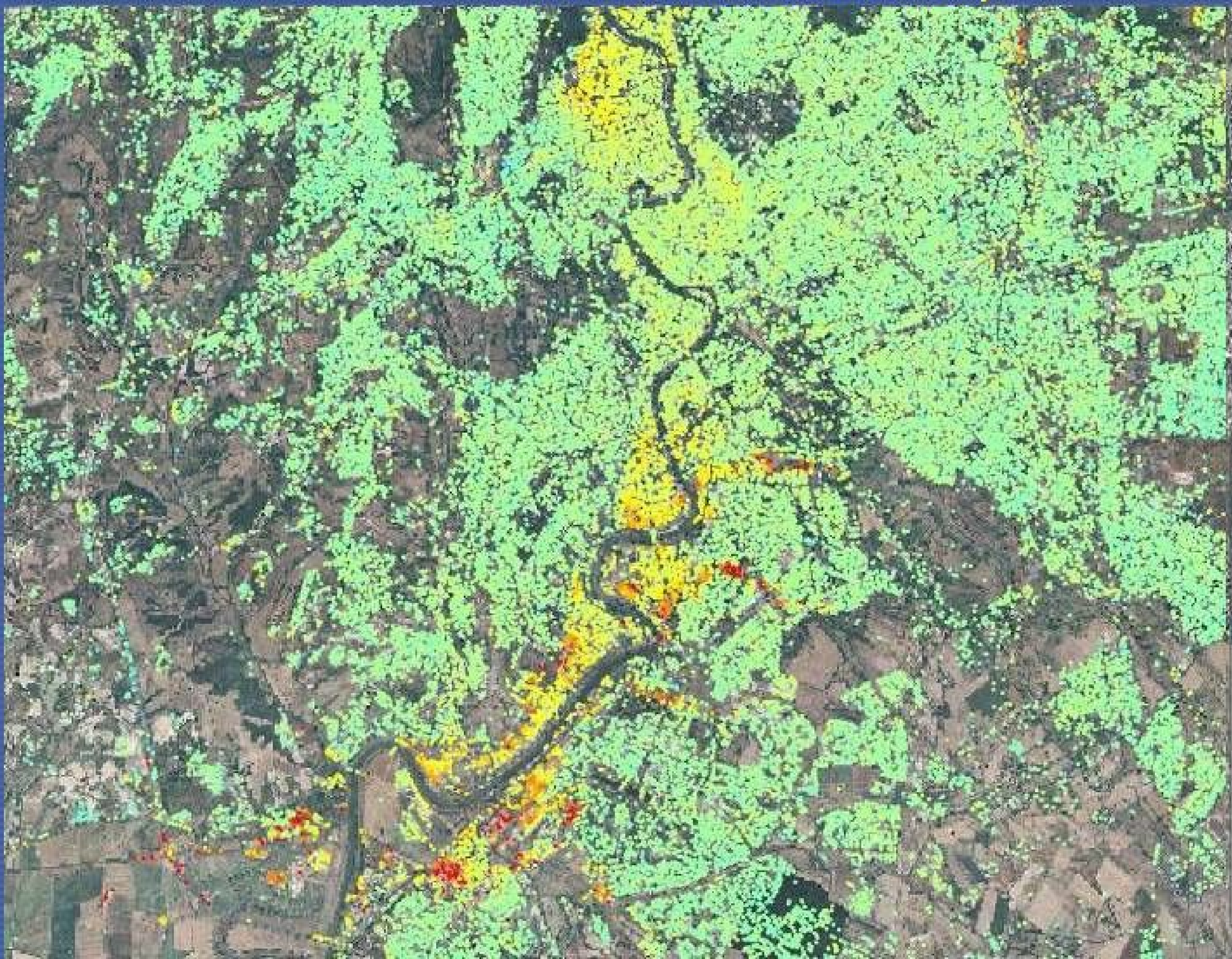
Geological, geophysical and geotechnical database

Studies of Quaternary formations or landforms



Geological, geophysical and geotechnical database

PS INSAR interferometry



Geological, geophysical and geotechnical database

Paganica Fault surface rupture April 6, 2009, Mw 6.3, L'Aquila eq.

Map of the capable faults and seismicity in Central Italy from the ANPA database, 1999

IAEA


Environmental
effects of the April 6,
2009, earthquake


Paleoseismic
environmental effects


Surface displacement
ca 1 m
ESI 2007 intensity X

Geological, geophysical and geotechnical database

SITE VICINITY

3.16 Site vicinity studies should cover a geographical area typically 5 km in radius.

In addition to providing a yet more detailed database for this smaller area, the objective of these investigations is to define in greater detail the neotectonic history of the faults, especially for determining the potential for and rate of fault displacement at the site (fault capability), and to identify conditions of potential geological instability of the site area.

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Geological, geophysical and geotechnical database

SITE VICINITY INVESTIGATIONS

- geomorphological–geological mapping;
- geophysical prospecting;
- boreholes;
- trenching.

PRODUCTS

- a geological map at a scale of 1:5000 and with appropriate cross-sections.
- age, type and amount of displacement of all the faults located in the area;
- identification and characterization of locations exhibiting potential hazards induced by natural phenomena and by human activities.

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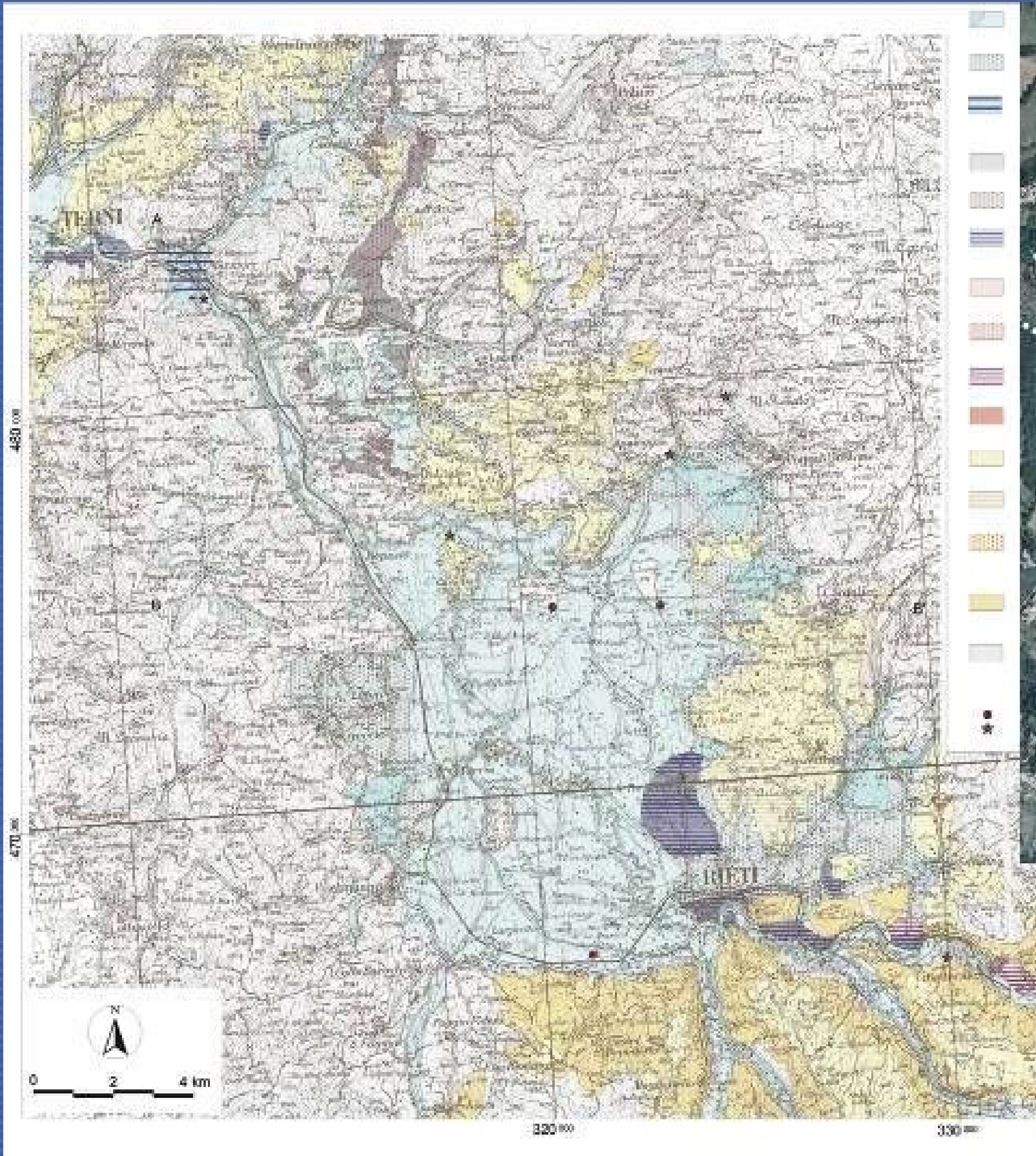
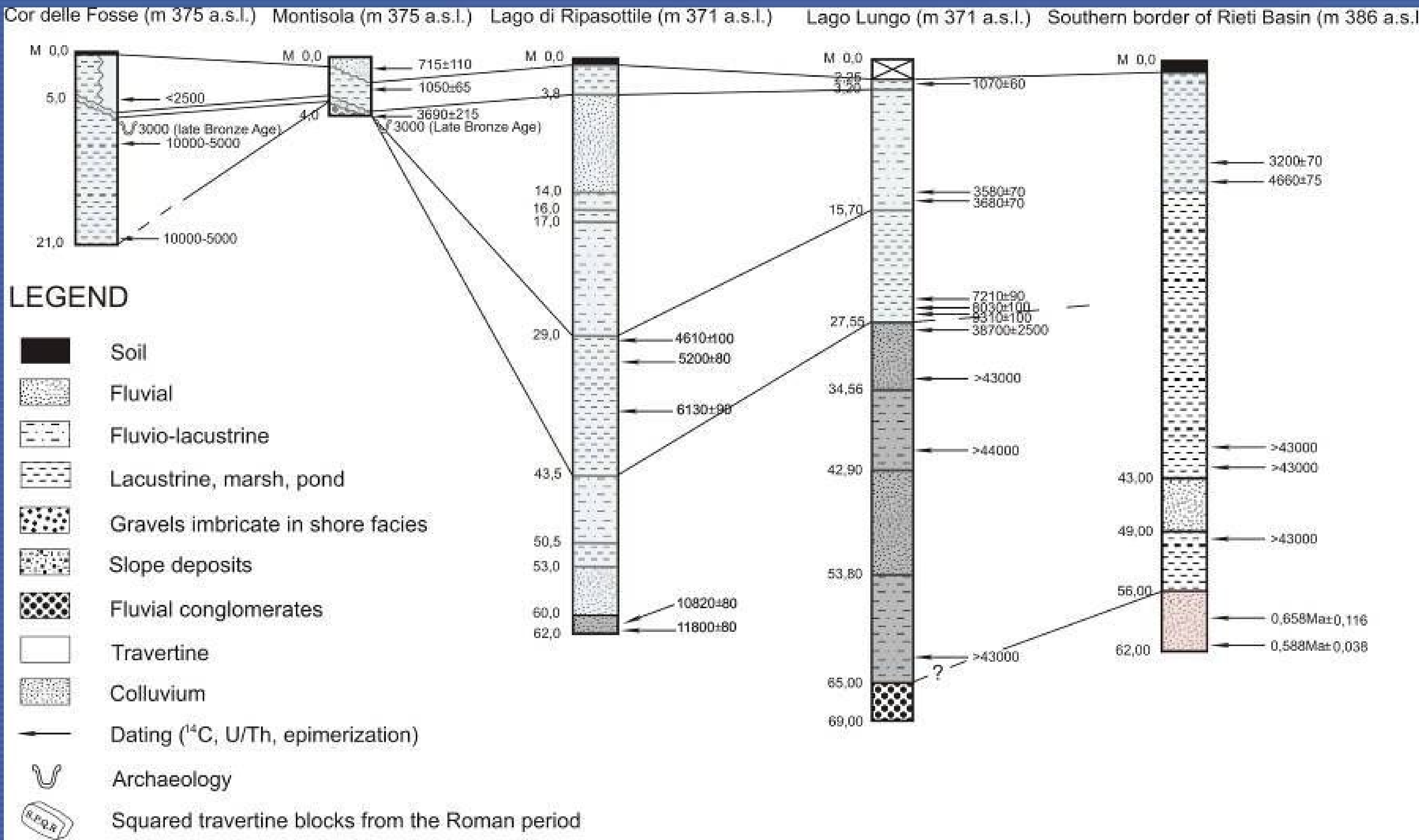
Geological, geophysical and geotechnical database

Geomorphological-geological mapping



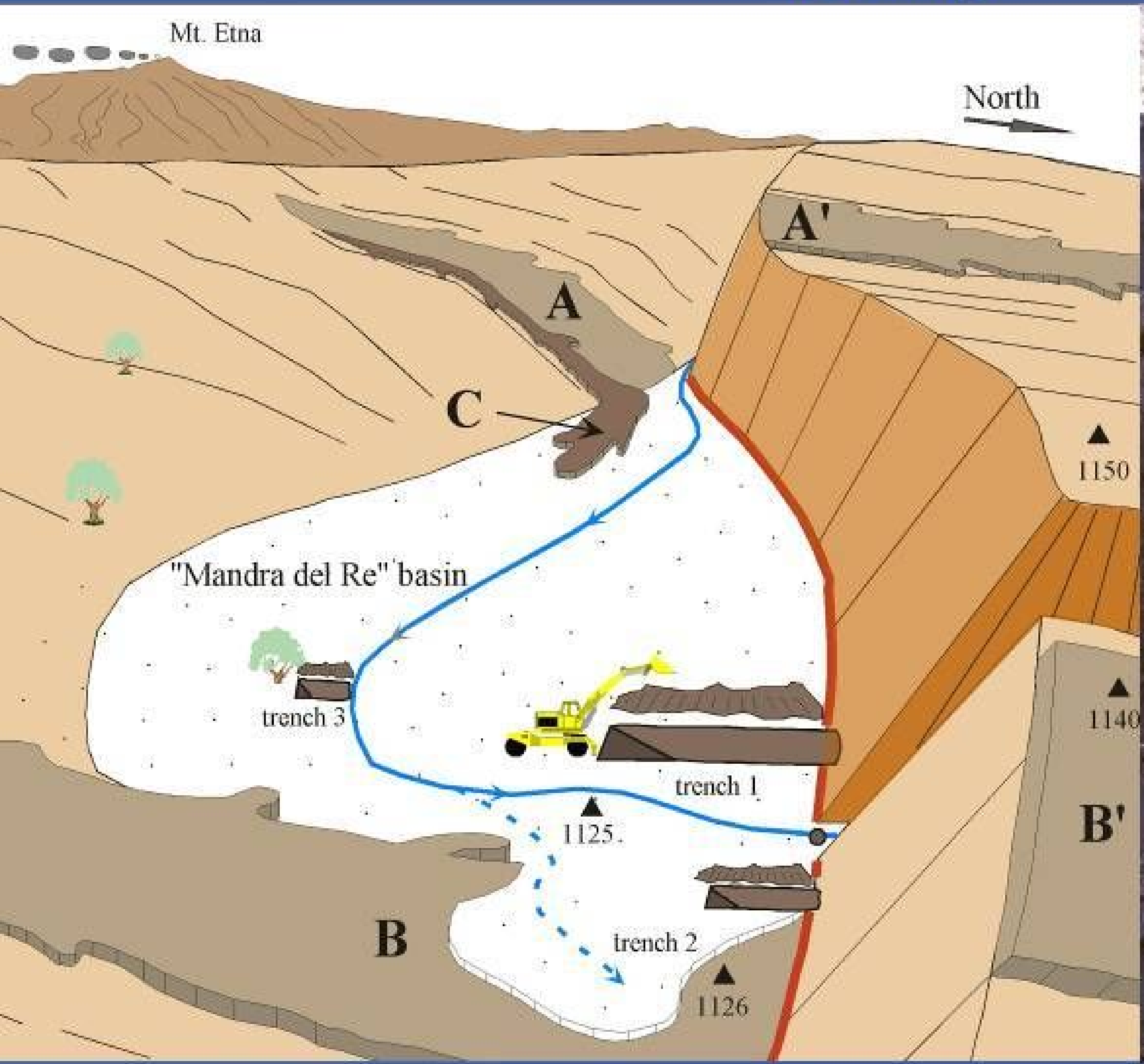
Geological, geophysical and geotechnical database

Correlations of boreholes



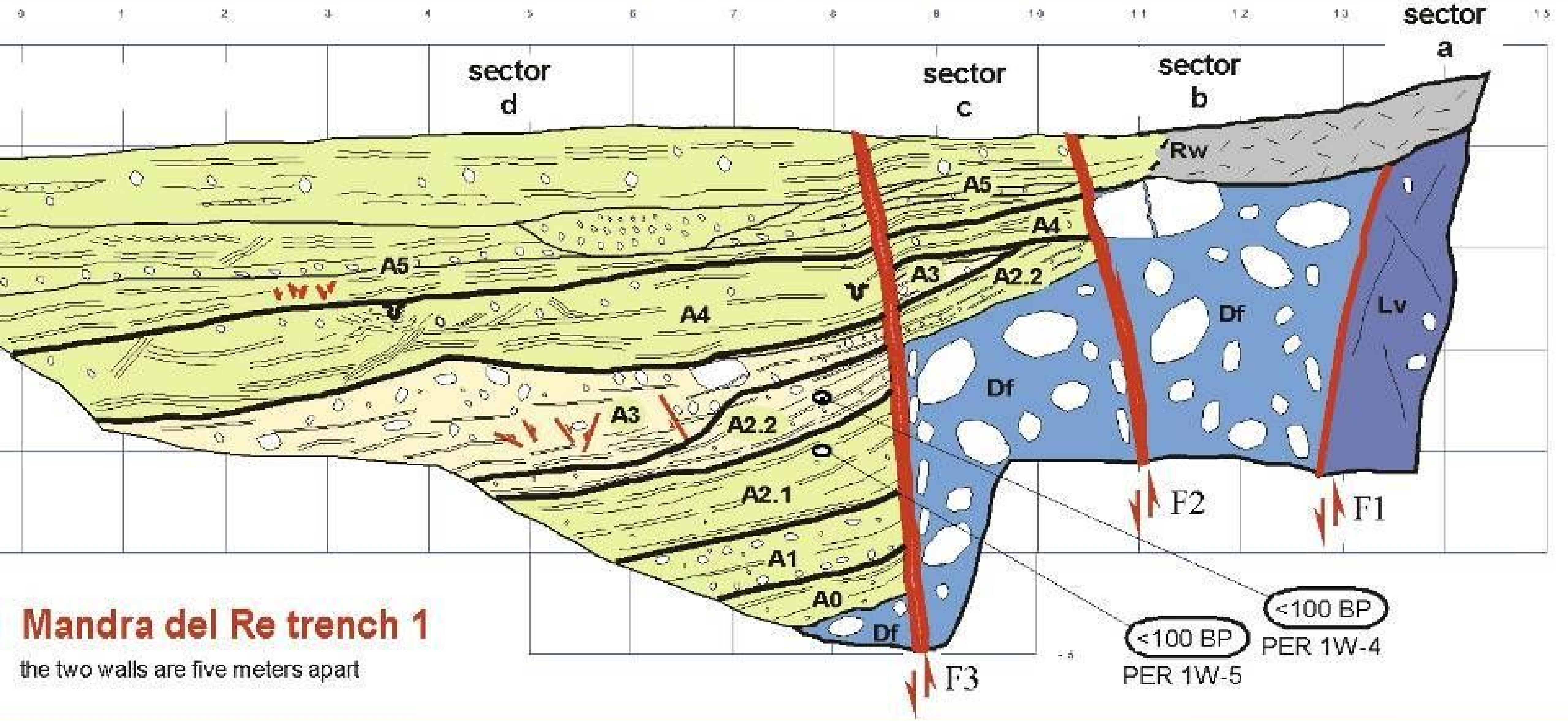
Geological, geophysical and geotechnical database

Trenching



Geological, geophysical and geotechnical database

Trenching



Mandra del Re trench 1

the two walls are five meters apart

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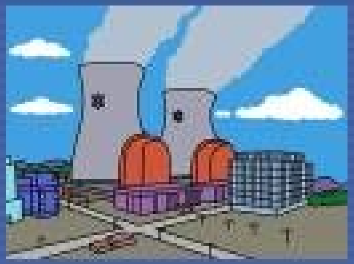
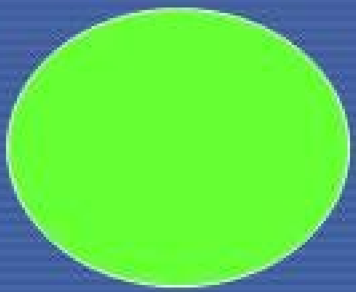
Geological, geophysical and geotechnical database

SITE AREA



3.19 Site area studies should include the entire area covered by the plant, which is typically 1 km^2. The primary objectives are:



(~1 km^2)

- to obtain detailed knowledge of the potential for permanent ground displacement;

- to provide information on the dynamical properties of foundation materials (such as P and S wave velocities), to be used in site response analysis.

The database should be developed from detailed geological, geophysical and geotechnical studies complemented by in situ and laboratory testing.

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Geological, geophysical and geotechnical database

SITE AREA INVESTIGATIONS - 1

The following investigations of the site area should be performed, using geological, geophysical, seismological and geotechnical techniques:

(1) Geological and geotechnical investigations: Investigations using boreholes or test excavations (including in situ testing), geophysical techniques and laboratory tests should be conducted to define the stratigraphy and structure of the site area and to determine the thickness, depth, dip, and static and dynamic properties of the different subsurface layers as may be required by engineering models (Poisson's ratio, Young's modulus, shear modulus, density, relative density, shear strength, consolidation and swelling characteristics, grain size distribution).

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Geological, geophysical and geotechnical database

SITE AREA INVESTIGATIONS - 2

(2) Hydrogeological investigations: Investigations using boreholes and other techniques should be conducted to define the geometry, physical and chemical properties, and steady state behaviour (recharge, transmissivity) of all aquifers in the site area, with the specific purpose of determining how they interact with the foundation.

(3) Investigations of site effects: The dynamic behaviour of the rock and soil at the site should be assessed, using available historical and instrumental data as a guide.

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Geological, geophysical and geotechnical database

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Geological, geophysical and geotechnical database

DYNAMIC SOIL-STRUCTURE INTERACTION

All the data required for assessing the dynamic soil–structure interaction should be acquired in the course of these investigations.

SCALE OF SITE AREA DATA

The data are typically presented on maps at a scale of 1:500 and with appropriate cross-sections.

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Geological, geophysical and geotechnical database

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Geological, geophysical and geotechnical database

Figure B.1 - The Mid Miocene, Marmarica Formation limestone, as sampled from to the borehole D11, at the depth of ca. 90-92 m below the ground surface.

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Geological, geophysical and geotechnical database

Figure B.2 - Borehole core showing a limestone with a small cavity of karstic origin, partly refilled by calcite.

IAEA

Geological, geophysical and geotechnical database

Figure C.1 – Outlet bay

Geological, geophysical and geotechnical database

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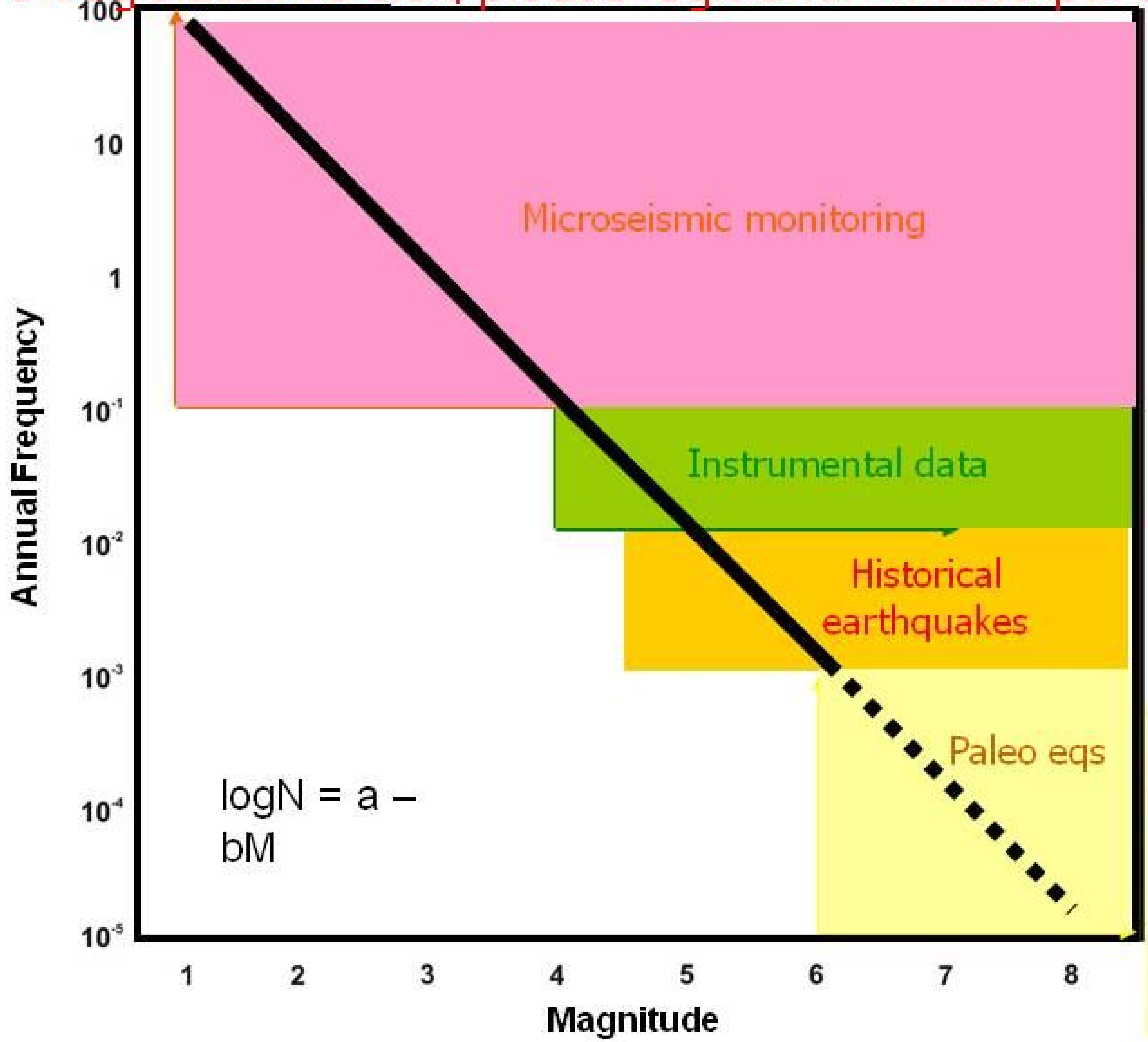
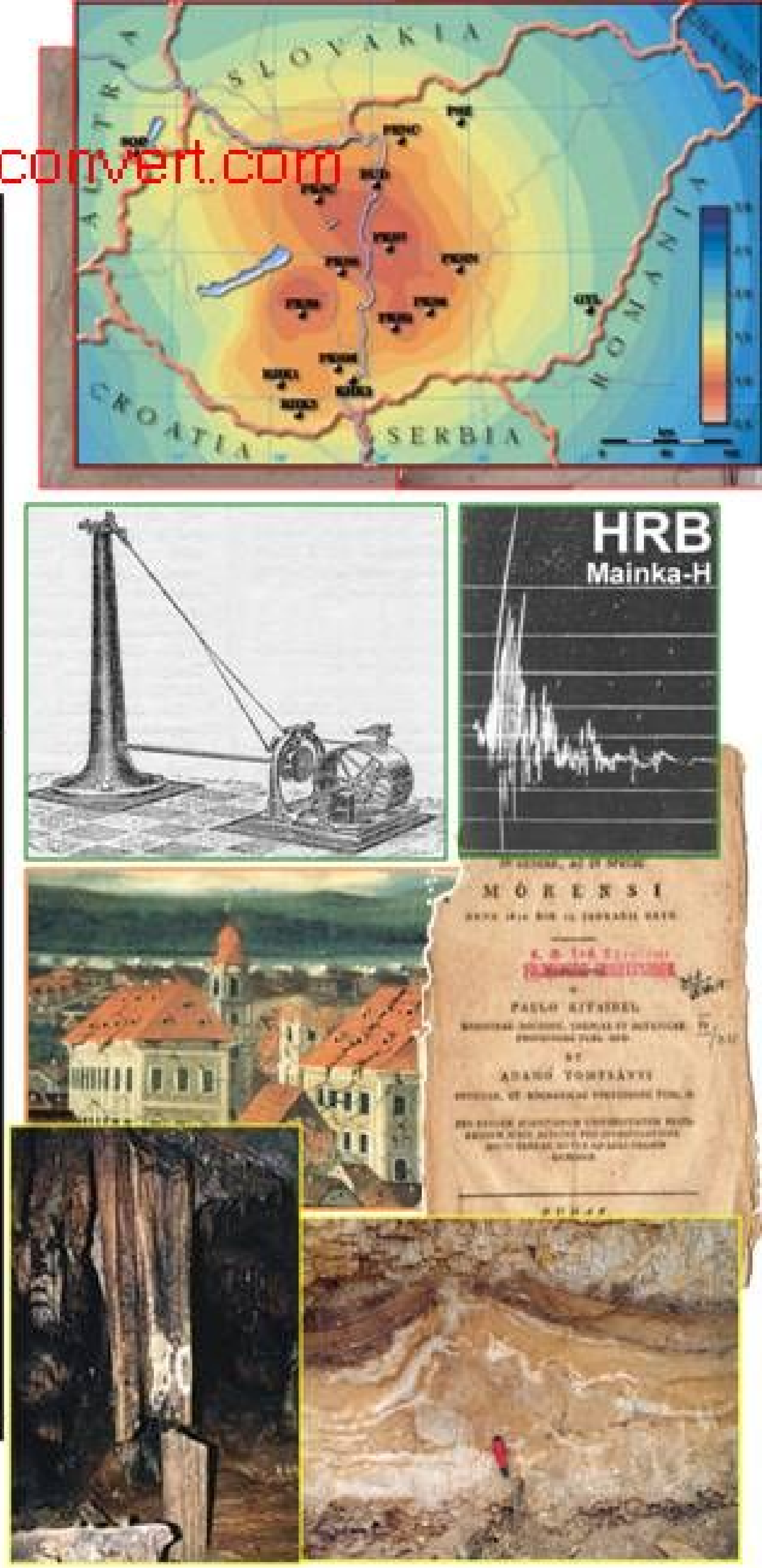
Seismological Database

What can we expect?





Geological, geophysical and geotechnical database

SEISMOLOGICAL DATABASE

Prehistorical and historical earthquake data (pre-instrumental data)

3.25. All 'pre-instrumental' data on historical earthquakes (that is, events for which no instrumental recording was possible) should be collected, extending as far back in time as possible. Palaeoseismic and archaeological information on historical and prehistorical earthquakes should also be taken into account.

3.26 The intensity scale used in the catalogue should be specified, since intensity levels can vary depending on the scale used. The magnitude and depth estimates for each earthquake should be based on relevant empirical relationships between instrumental data and macroseismic information, which may be developed from the database directly from intensity data or by using isoseismals.

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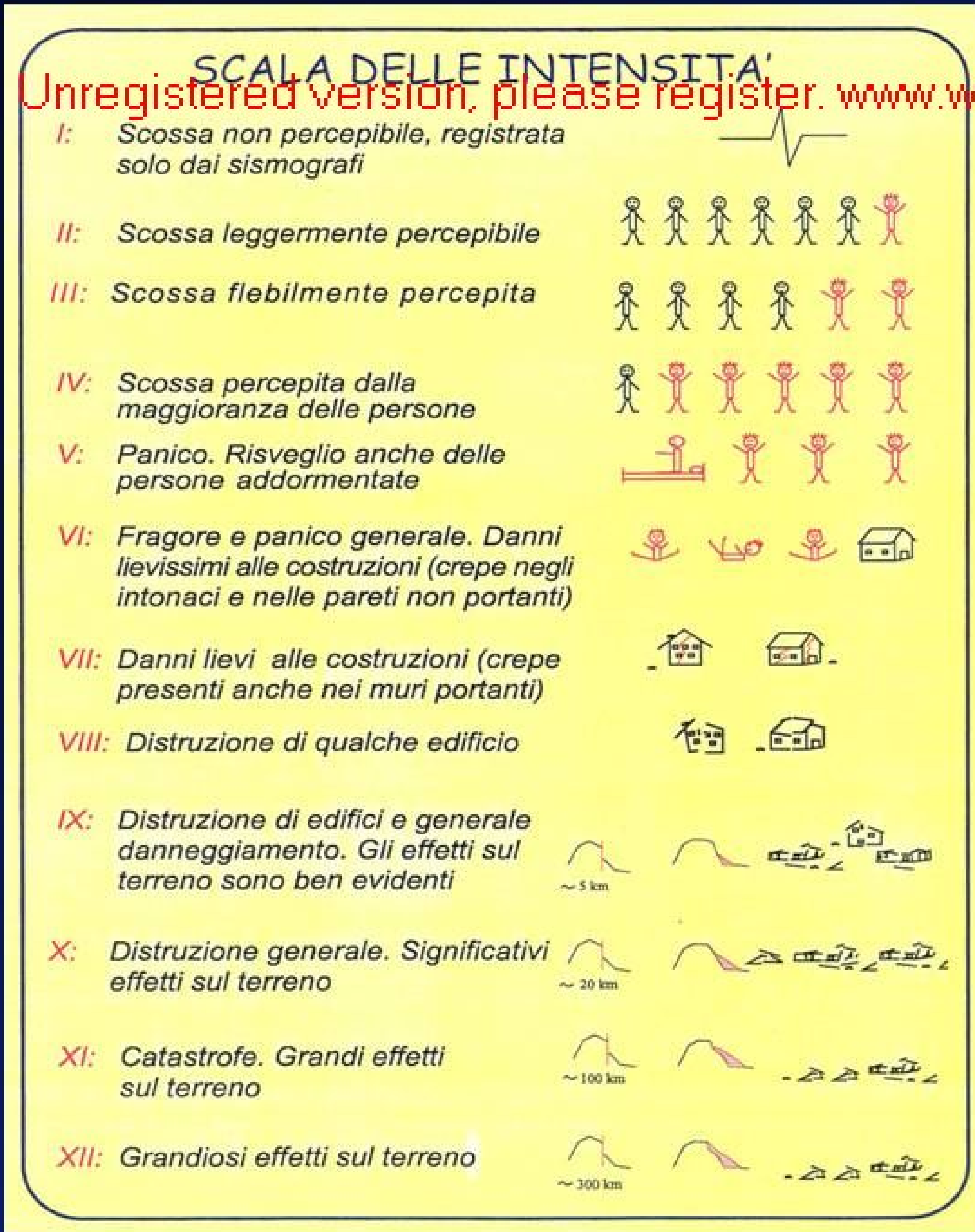


Basic structure of 12 degrees scales

MCS Scale
Mercalli – Cancani – Sieberg (1930)
Mostly used in S Europe

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

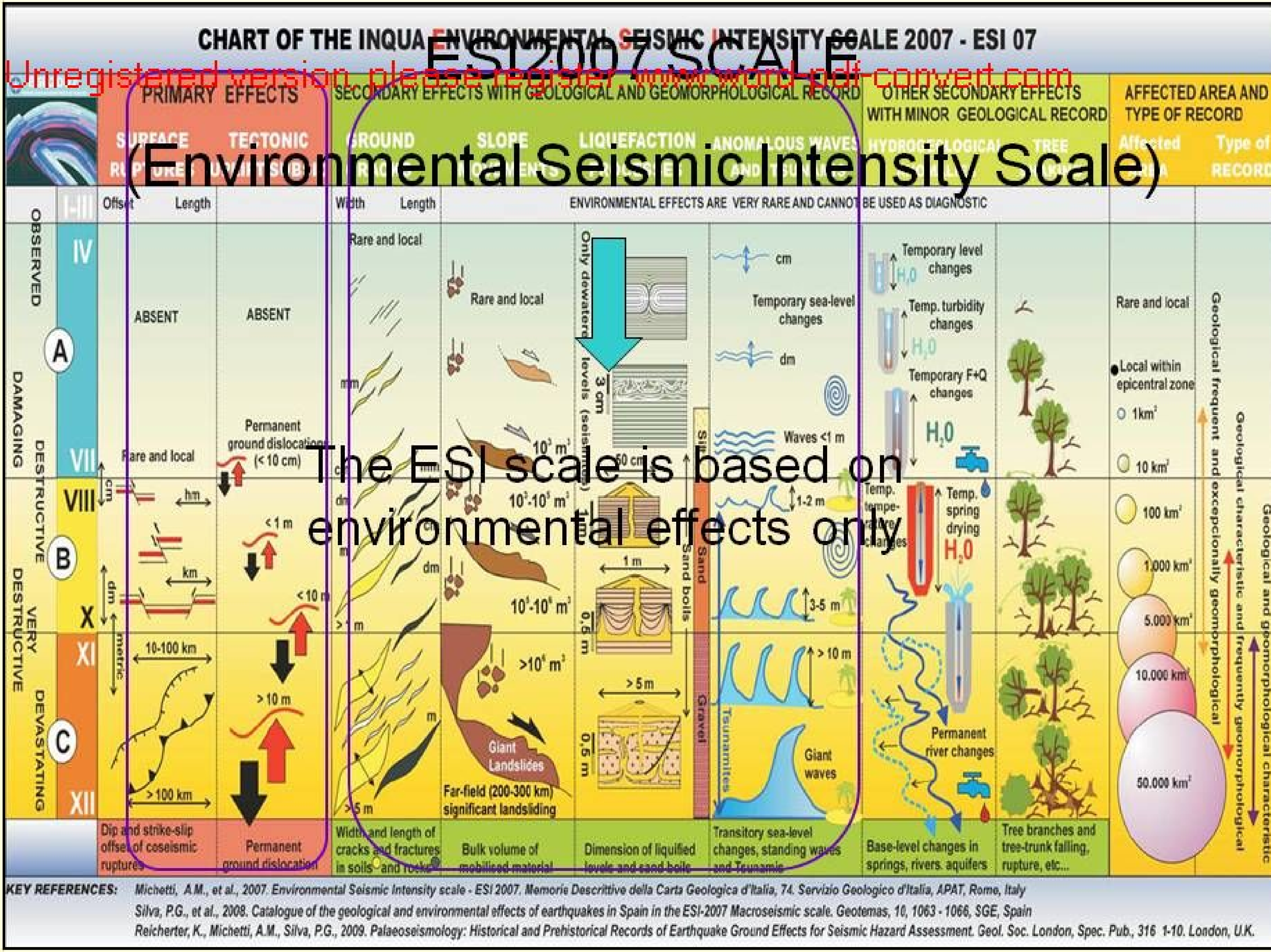
B. **Damage saturates at intensity X in most cases**

C. **Invaluable information, cannot be replaced by instrumental records**

ESI2007 SCALE

(Environmental Seismic Intensity Scale)

The ESI scale is based on environmental effects only



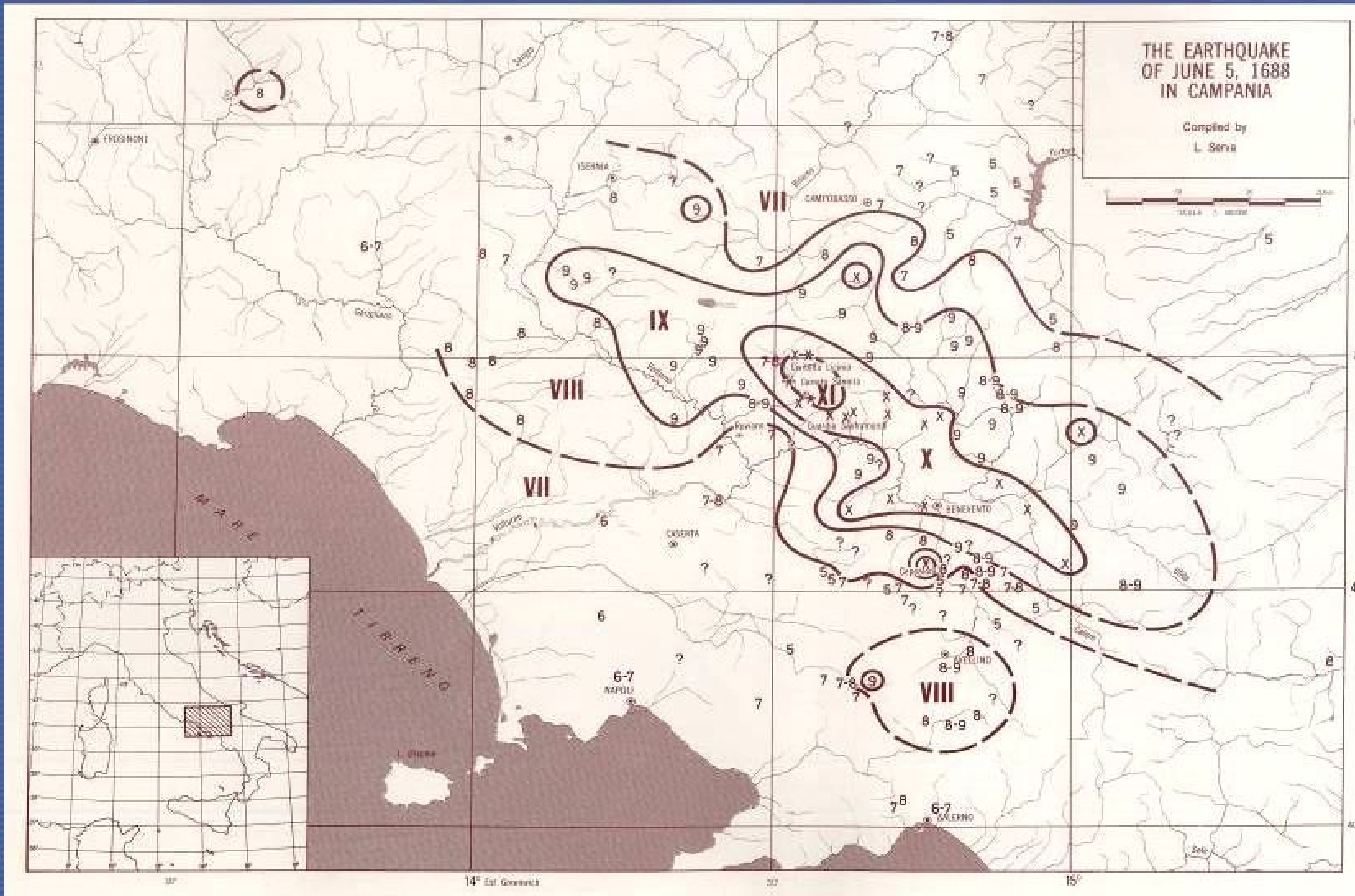
List of earthquakes for which the reported difference in epicentral intensity defined on MM and ESI2007 scales is two degrees or more

LOC.	EQ.	DATE	Ms.Me	I_0 MM	SRL (KM)	MAXD (m)	ESI 2007	REFERENCE
Pakistan	Quetta	30.05 1935	7.6	9	150		11	Stirling et al, 2002 http://www.boloji.com/environment/68.htm http://www.seismosoc.org/publications/SRL/SRL_74/srl_74-2_ambraseys_esupp1.html
USA, California	Arroyo Salada	19.03 1954	6.2	6	15	0.50	10	Wells L.D. & Coppersmith J.K., 1994 Stover W.C., Coffman L.J., 1993 http://www.ngdc.noaa.gov/seg/hazard/int_srch.shtml Wang H. & Tao X., 2003 http://www.gps.caltech.edu/~sieh/pubs_docs/papers/P88b.pdf
Mexico	San Miguel	09.02 1956	6.9	6	22	0.90	10	Wells L.D. & Coppersmith J.K., 1994 http://midas.upr.clu.edu/ipgh-search.html
USA, Alaska	Huslia	07.04 1958	7.3	8	64	1.35	10	Wells L.D. & Coppersmith J.K., 1994 http://www.ngdc.noaa.gov/seg/hazard/int_srch.shtml
USA, Alaska	Prince William Sound	28.03 1964	9.2	10	500	7-20	12	Kanamori 1977 Atwater et al., 2005 Abe K., 1995 http://earthquake.usgs.gov/regional/states/events/1964_03_28.php http://www.ngdc.noaa.gov/seg/hazard/sig_srch_idb.shtml http://neic.usgs.gov/neis/eq_depot/usa/1964_03_28_iso.html
Congo	Toro	20.03 1966	7.0	7	40	2.50	10	Yeats S.A. et alii 1997 http://neic.usgs.gov/neis/epic/epic_global.html http://www.ngdc.noaa.gov/seg/hazard/sig_srch_idb.shtml
Russia	Tajikistan-Xinjiang border region	11.08 1974	7.3	7-8	30	1.20	10	Wells L.D. & Coppersmith J.K., 1994 Nikonov A.A. et alii 1983 Wang H. & Tao X., 2003 http://iisee.kenken.go.jp/utsu/utsuweq_bak_eng.html Stirling et al , 2002
Uzbekistan	Gazli	08.04 1976	7.3	7	30		10	Wells L.D. & Coppersmith J.K., 1994 http://www.seismology.harvard.edu/CMTsearch.html Wang H. & Tao X., 2003 http://www.gesource.ac.uk/roads/cgi-bin/earthquakefull.pl?id=4857
USA, California	Mammoth Lakes	27.05 1980	6.0	6	20	0.50	10	Wells L.D. & Coppersmith J.K., 1994 Yeats S.A. et alii 1997 http://earthquake.usgs.gov/eqcenter/eqarchives/significant/sig_1980.php

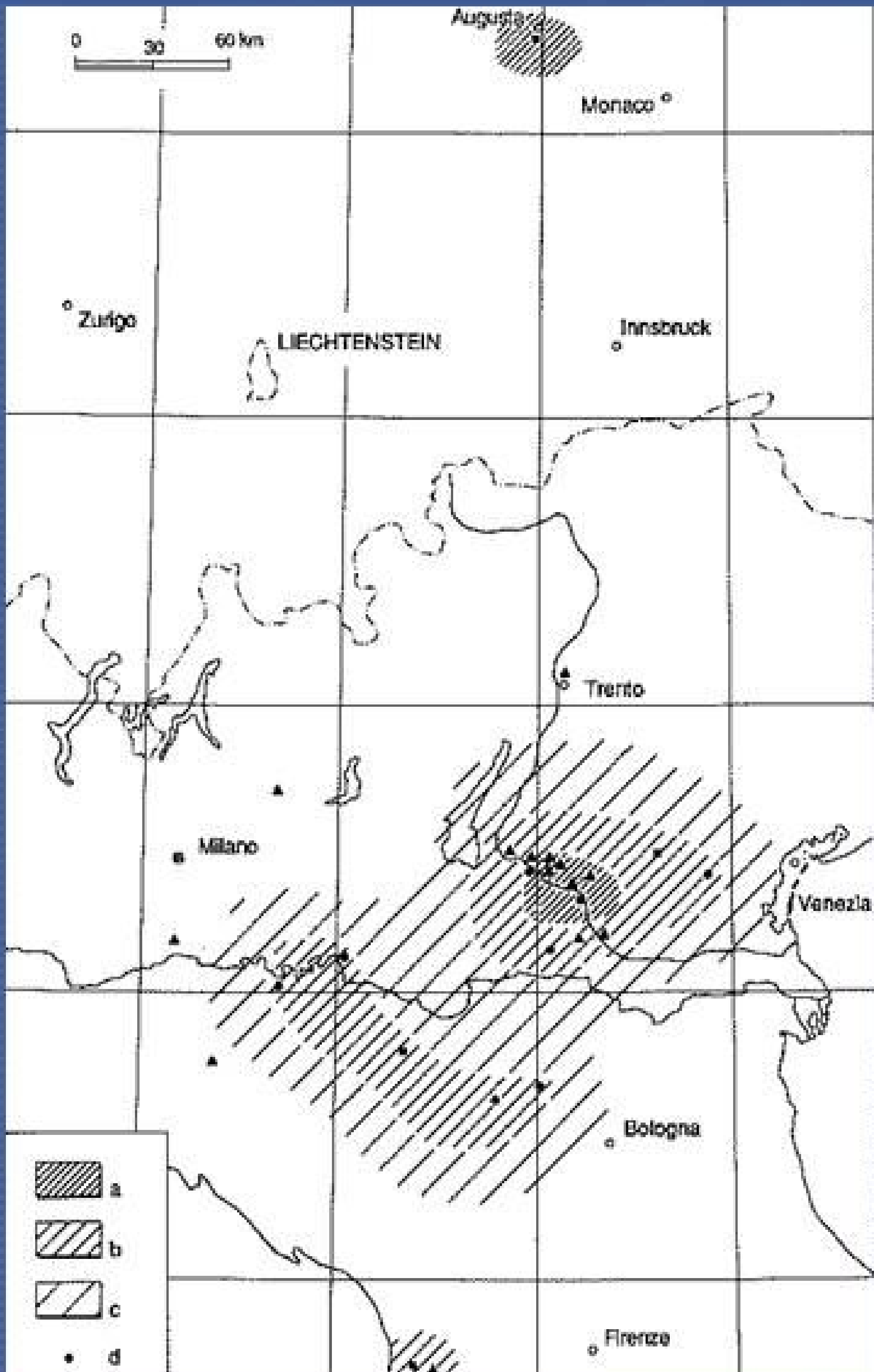
LOC.	EQ.	DATE	Ms.Me	I_0 MM	SRL (KM)	MAXD (m)	ESI 2007	REFERENCE
Papua New Guinea	New Ireland - Rabaul	03.07 1985	7.2	7	48		11	http://earthquake.usgs.gov/eqcenter/eqarchives/significant/sig_1985.php Wells L.D. & Coppersmith J.K., 1994 Wang H. & Tao X., 2003 http://www.ngdc.noaa.gov/seg/hazard/sig_srch_idb.shtml
USA, California	Kettleman Hills	04.08 1985	5.9	6	20		10	http://earthquake.usgs.gov/eqcenter/eqarchives/significant/sig_1985.php Wells L.D. & Coppersmith J.K., 1994 Wang H. & Tao X., 2003
Canada	Nahanni	05.10 1985	6.6	6	32		10	http://earthquake.usgs.gov/eqcenter/eqarchives/significant/sig_1985.php Wells L.D. & Coppersmith J.K., 1994 Wang H. & Tao X., 2003 http://www.ngdc.noaa.gov/seg/hazard/sig_srch_idb.shtml
Philippines	Luzon	16.07 1990	7.8	7 (9)	120	6.20	11	Wells L.D. & Coppersmith J.K., 1994 http://www.gesource.ac.uk/roads/cgi-bin/earthquakefull.pl?id=5408 http://www.ngdc.noaa.gov/seg/hazard/sig_srch_idb.shtml
Kyrgyzstan	Suusamyr	19.08 1992	7.5	9	80	2.70	11	Yeats S.A. et alii 1997 http://www.seismology.harvard.edu/CMTsearch.html http://www.ngdc.noaa.gov/seg/hazard/sig_srch_idb.shtml http://www.scgis.ru/russian/cp1251/h_dgggms/1-99/yunga-e.htm
Philippines	Mindoro	15.11 1994	7.1	7	>15	3.00	10	Yeats S.A. et alii 1997 http://earthquake.usgs.gov/eqcenter/eqarchives/significant/sig_1994.php http://www.ngdc.noaa.gov/seg/hazard/sig_srch_idb.shtml
Taiwan	Chi-Chi	20.09 1999	7.7	9	83	11.30	11	Stirling et al, 2002 Hsu et al, 2002 Solokov & Wald, 2002
Perù	Coast of Perù	23.06 2001	8.2	8	200	5.50	11	http://iisee.kenken.go.jp/quakes/2001peru/index.htm Tavera et al., 2002 Kikuchi & Yamanaka, 2001 Ruegg et al., 2001 http://neic.usgs.gov/neis/eq_depot/2001/eq_010623/
USA, Alaska	Denali National Park	03.11 2002	7.9	8 (9)	340 (330)	8.80	11	Haeussler et al., 2004, http://www.aeic.alaska.edu/Seis/Denali_Fault_2002/ http://pasadena.wr.usgs.gov/shake/ak/STORE/X22614036/ciim_display.htm Celebi, 2004 Rowe et alii, 2004
Indonesia	Sumatra-Andaman Island	26.12 2004	9.0	9 (8)	1300 (1500)	20.0	12	Bilham et al., 2005 http://earthquake.usgs.gov/eqcenter/eqinthenews/2004/usslav/ Martin, 2005 Banerijee P., 2007

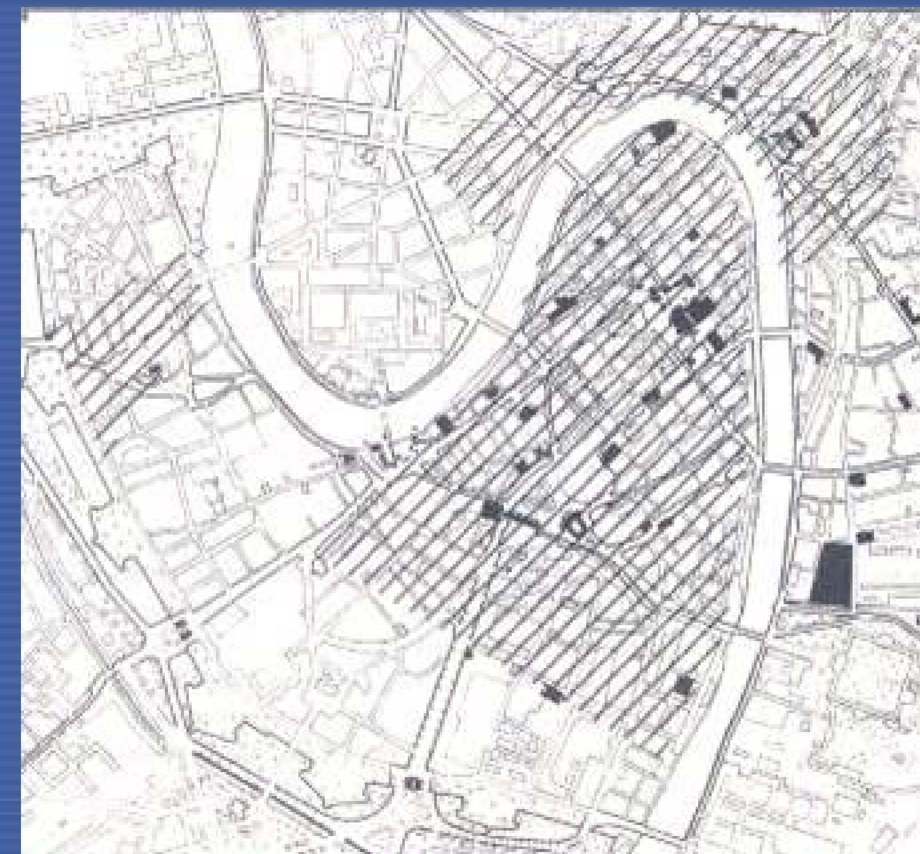
Geological, geophysical and geotechnical database

Isoseismal maps



Geological, geophysical and geotechnical database





The center of Verona was severely damaged

Macroseismic field of 1117 earthquake

Legend:

Inferred Intensity, a) IX MCS; b) VIII MCS; c) VII MCS; d) Places with notice of damage; e) Places with damages supposed by archaeological informations

Geological, geophysical and geotechnical database

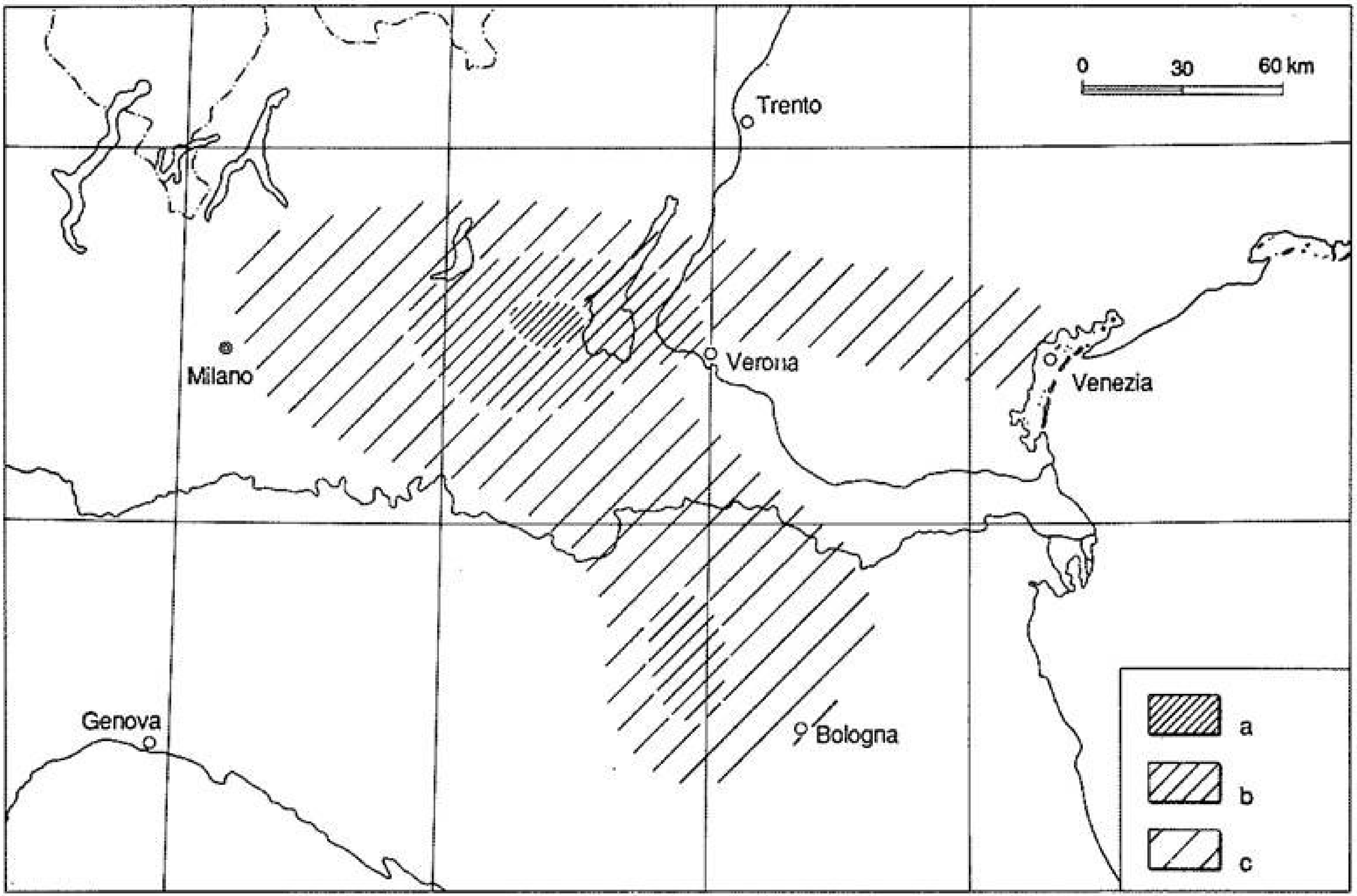
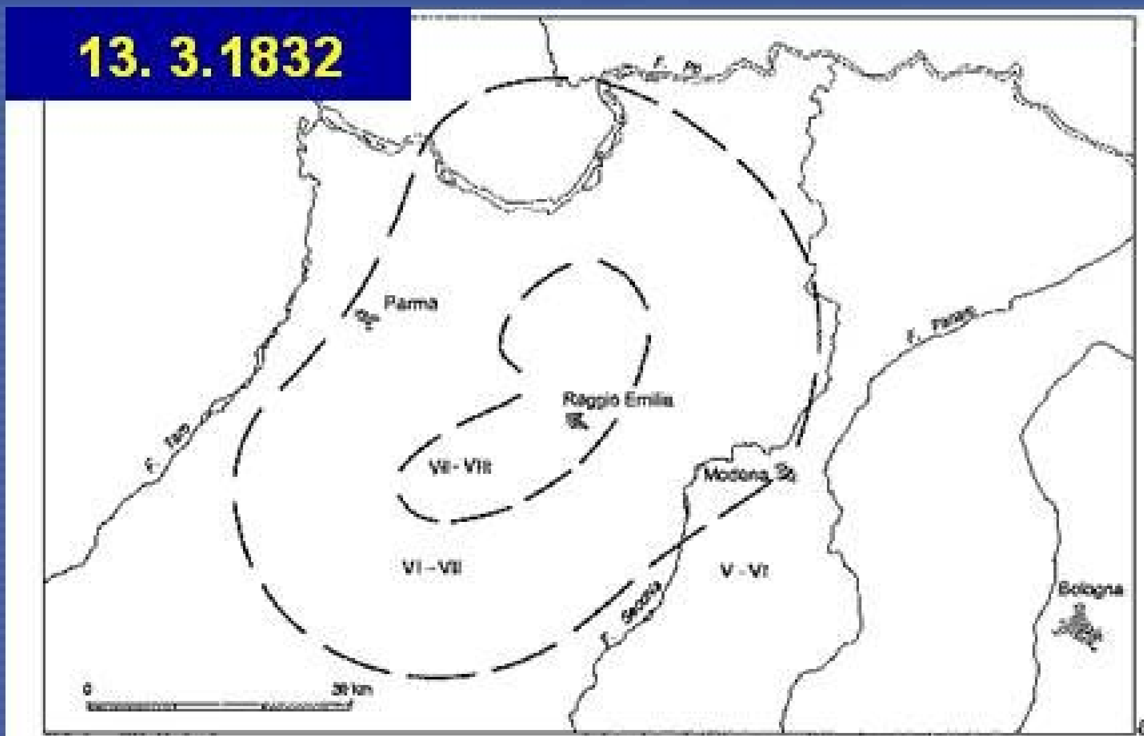


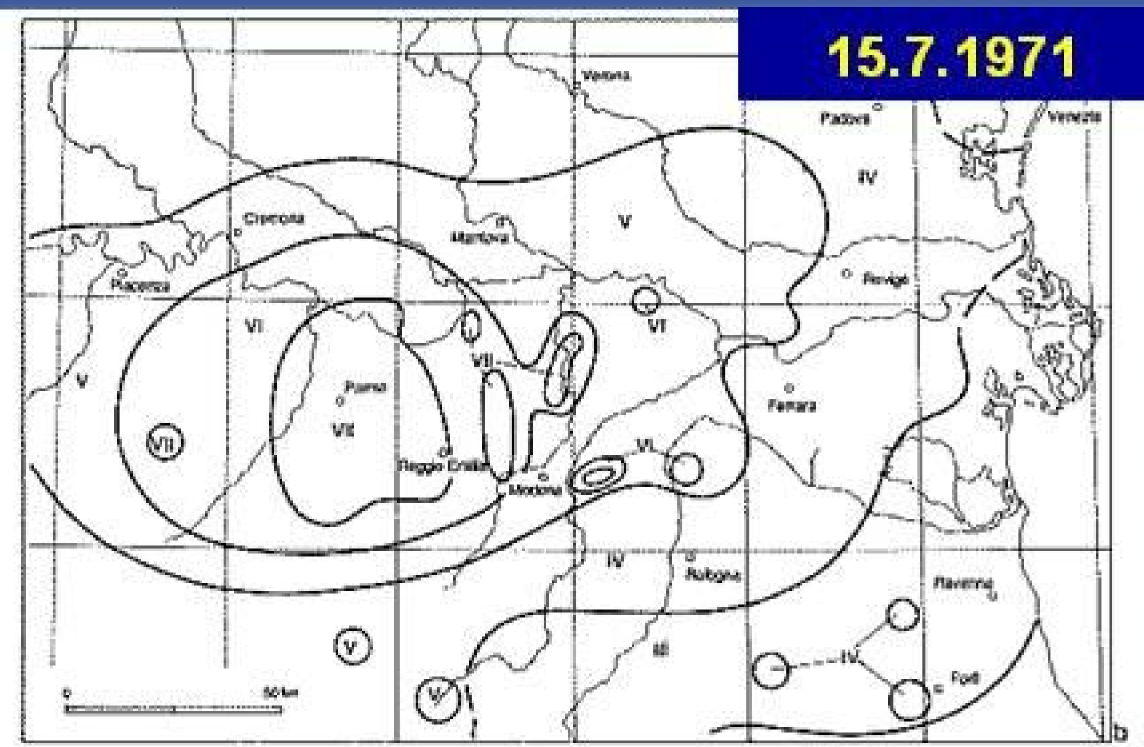
Fig. 7 - Terremoto del 1222, ipotesi di campo macrosismico. *Legenda:* Intensità stimata, *a)* IX-X MCS; *b)* VIII MCS; *c)* VII MCS. Da Magri & Molin, 1986; *ridisegnato.*

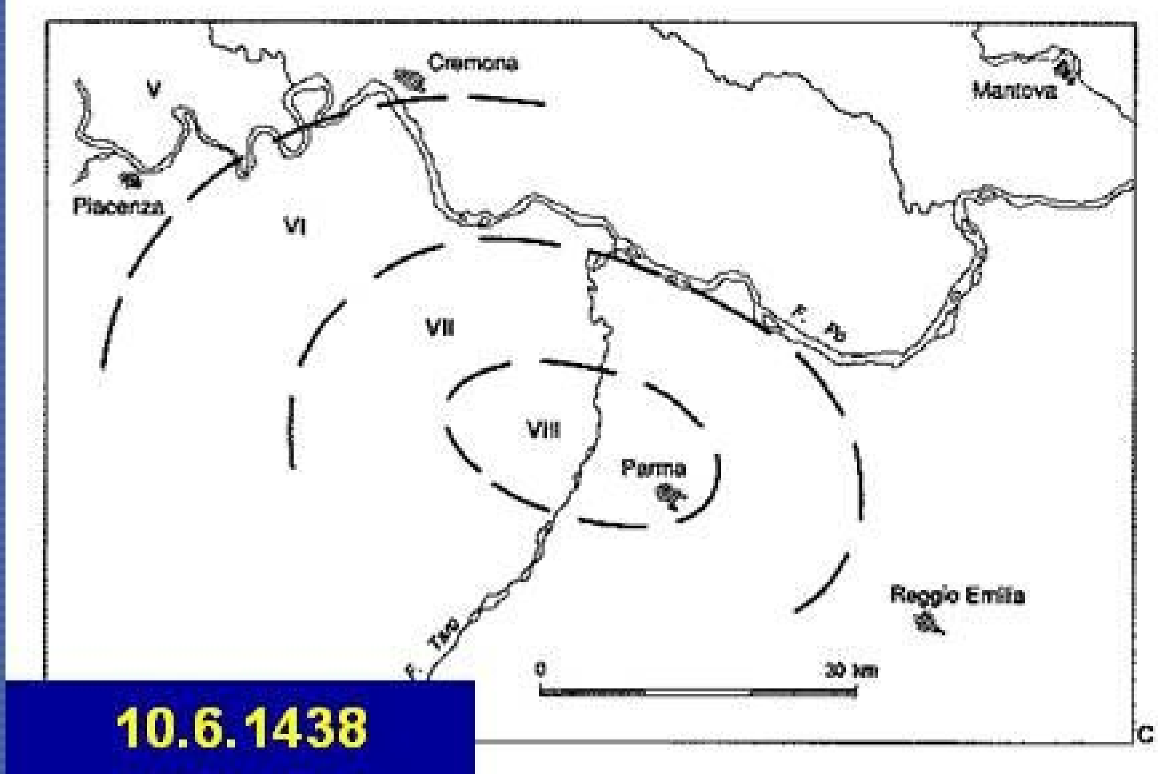
Geological, geophysical and geotechnical database

13. 3.1832

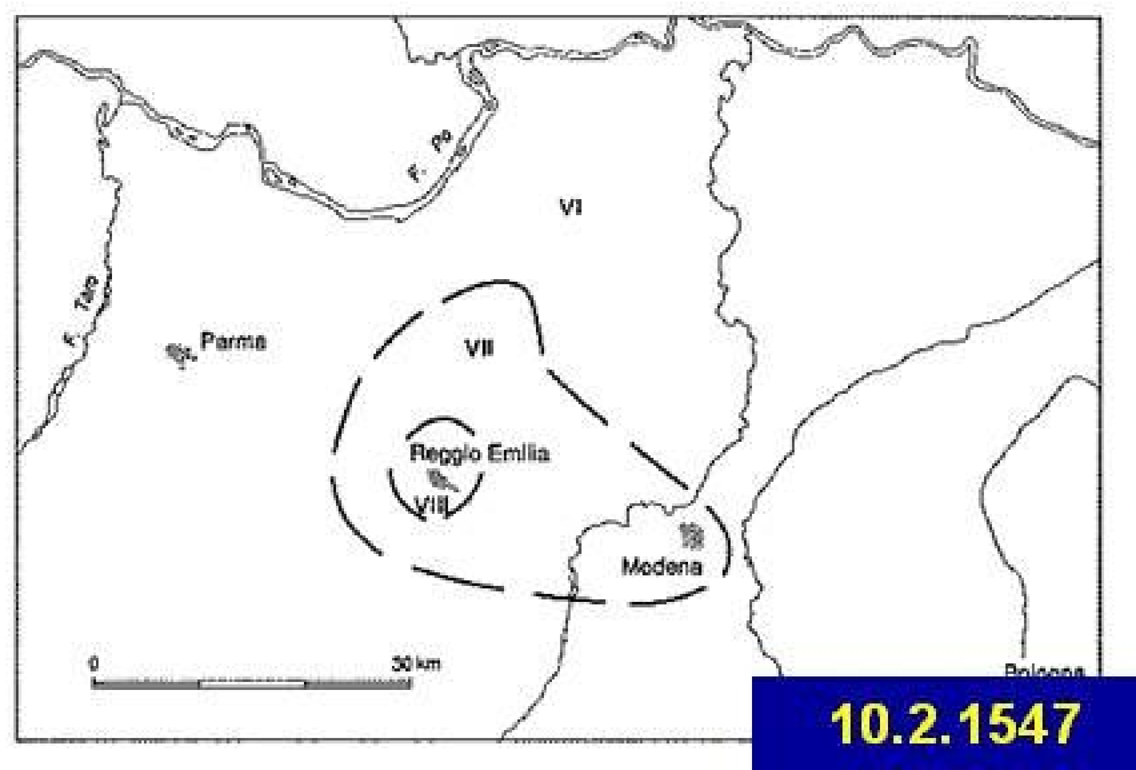


15.7.1971





10.6.1438



10.2.1547

Geological, geophysical and geotechnical database

DATA TO BE COLLECTED

- date and time of the event;
- location of the macroseismic epicentre, estimated focal depth and magnitude;
- maximum intensity and, if different, intensity at the macroseismic epicentre, with a description of local conditions;
- isoseismal contours;
- estimates of uncertainty for all of the above parameters;
- intensity of the earthquake at the site, together with details of effects on the soil;
- an assessment of the quality and quantity of data from which the above parameters have been estimated.

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Geological, geophysical and geotechnical database

The intensity scale used in the catalogue should be specified.

The magnitude and depth estimates for such earthquakes should be based on relevant empirical relationships between instrumental data and macroseismic information.

When the catalogue of relevant historical earthquake data has been compiled, its completeness and reliability should be assessed. This point will be fundamental to a properly conducted seismic hazard evaluation.

In general, the catalogues are incomplete for small magnitude events owing to the threshold of recording sensitivity, and for large magnitude events owing to their long recurrence intervals.

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Geological, geophysical and geotechnical database

Instrumental earthquake data

Data to be collected include:

- time of origin and location of epicentre and hypocentre;
- all magnitude determinations, including those on different scales, and any information on seismic moment or stress drop;
- dimensions and geometry of the fore-shock and aftershock zones;
- other information that may be helpful in understanding the seismotectonic regime, such as focal mechanism, stress drop and other source parameters;
- estimates of uncertainty for each of the above parameters;
- macroseismic details.

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Geological, geophysical and geotechnical database

When the catalogue of relevant instrumental earthquakes has been compiled, its reliability and completeness should be assessed.

In addition to catalogues maintained by individual States or neighbouring States, worldwide instrumental earthquake catalogues are maintained by various organizations such as the International Seismological Centre, the United States National Earthquake Information Center and the European–Mediterranean Seismological Centre in France.

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Geological, geophysical and geotechnical database

Site specific instrumental data

It is often useful to operate a network of sensitive seismographs having a recording capability for micro-earthquakes.

The minimum monitoring period necessary to obtain meaningful data for seismotectonic interpretation is several years for regions of high seismicity, and may be longer for regions of low seismicity.

Earthquakes recorded within and near such a network should be carefully analysed in connection with seismotectonic studies of the near region.

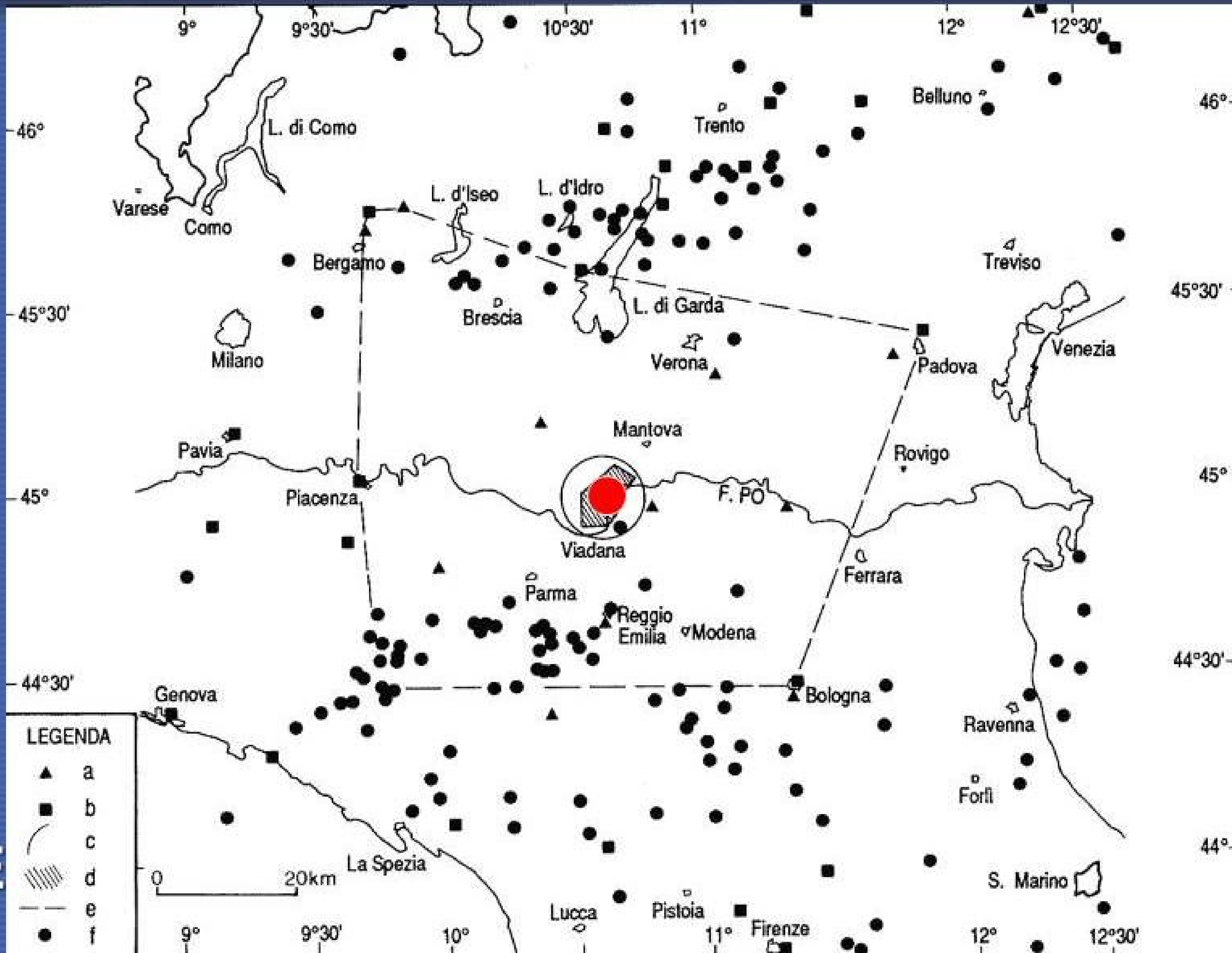
Wherever possible, recordings of regional strong ground motion should be collected. Strong motion accelerographs should be installed permanently within the site area.

Geological, geophysical and geotechnical database

Viadana (Northern Italy):

local instrumental seismicity

(1983-1984)



SUMMARY

- Introduction
- Glossary
- Necessary information and investigations (database)
- Construction of a regional seismotectonic model
- Potential for fault displacement at or near the site

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Construction of a regional seismotectonic model

4.1 INTRODUCTION

The link between the database and any model for deriving hazard levels is a regional seismotectonic model which should be based on a coherent merging of the regional databases.

In the construction of such a model, all existing interpretations of the seismotectonics of the region that may be found in the available literature should be taken into account.

Above all, a sound database is essential in the construction of a reliable seismotectonic model. The most sophisticated methods will not yield good models if the database is poor or insufficient.

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Construction of a regional seismotectonic model

INTRODUCTION 2

4.2 The standard procedure is to integrate the elements of the seismological, geophysical and geological databases in order to construct a coherent seismotectonic model (or alternative models) consisting of a discrete set of seismogenic structures.

4.3 The seismogenic structures identified may not explain all the observed earthquake activity. This is because seismogenic structures may exist without recognized surface or subsurface manifestations and because of the timescales involved; for example, fault displacements may have long recurrence intervals with respect to seismological observation periods.

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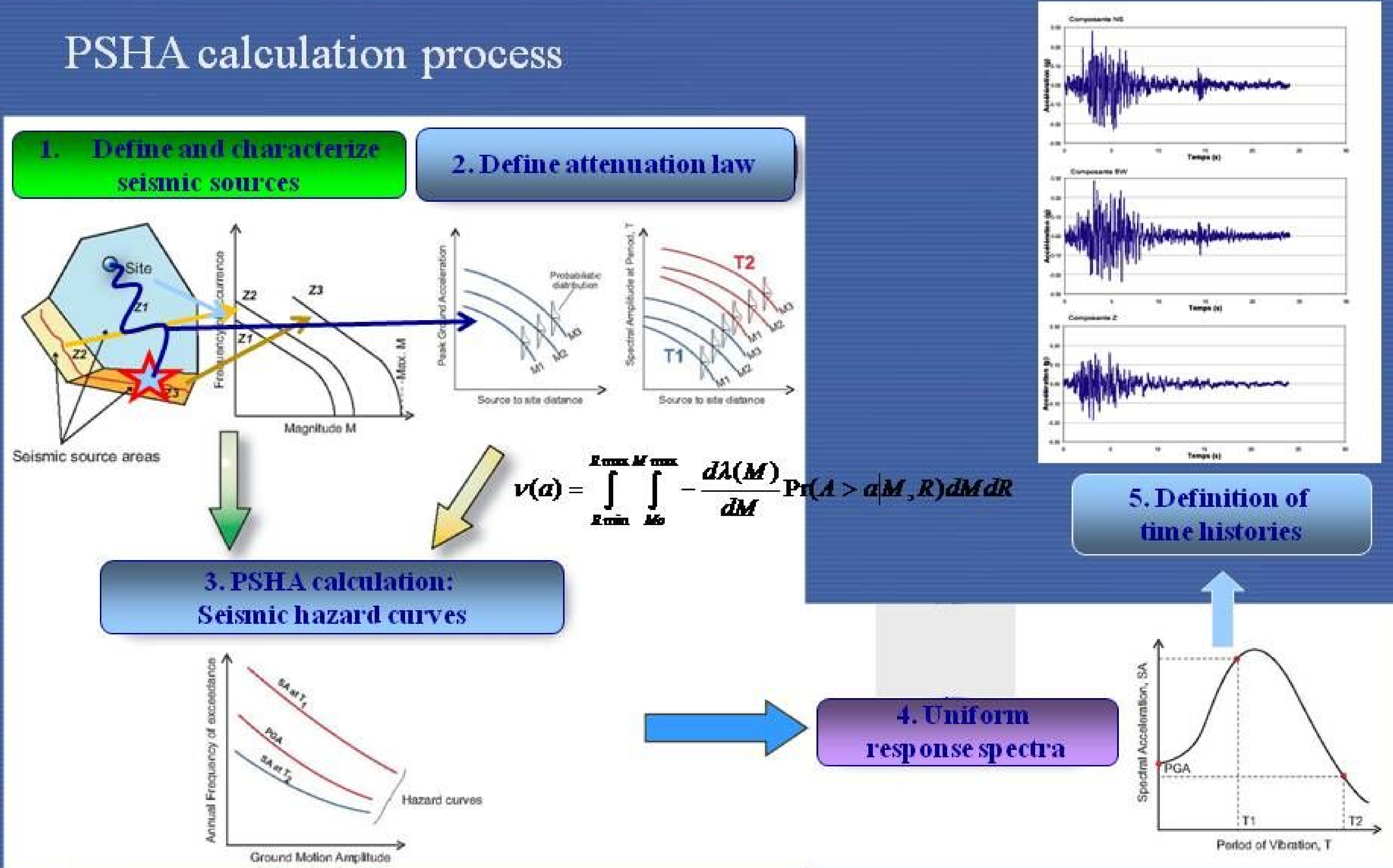
Safety Guide (SSG-9)

PSHA calculation process



Construction of a regional seismotectonic model

4.4 Consequently, any seismotectonic model consists, to a greater or lesser extent, of two types of seismic sources:

- those seismogenic structures which can be identified by using the available database;
- diffuse seismicity (consisting usually, but not always, of small to moderate earthquakes) which is not attributable to specific structures identified by using the available database.

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Construction of a regional seismotectonic model

4.5 Evaluation and characterization of both these types of seismic sources involve assessments of uncertainty.

However, the second type, diffuse seismicity, is a particularly complex problem in seismic hazard evaluation and generally will involve greater uncertainty because the sources of the earthquakes are not well understood.

The uncertainty in the interpretations should be properly assessed in order to incorporate it into the evaluation of the ground motion hazard at the site. This assessment should typically involve alternative interpretations and the weighting of each alternative according to the interpreted degree of support that it has in the data.

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Construction of a regional seismotectonic model

Although attempts should be made to define all the parameters of each element in a seismotectonic model, the construction of the model should be data driven, and any tendency to interpret data only in a manner that supports some preconception should be avoided.

When it is possible to construct alternative models which explain the observed seismological, geophysical and geological data sufficiently well, and the differences cannot be resolved by means of additional investigations within a reasonable timeframe, the final hazard evaluation should take into consideration all such models, with appropriate weights, in order to fully express the uncertainty contained in the seismotectonic model.

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Construction of a regional seismotectonic model

SEISMOGENIC STRUCTURES

4.14 All seismogenic structures that may have significance for contributing to the ground motion and fault displacement hazard at the site should be included in the seismotectonic model.

4.15. With regard to the ground motion hazard, the concern lies with those seismogenic structures whose combination of location and earthquake potential could contribute to seismic hazard at the site over the range of ground motion frequencies of interest.

4.16. With regard to the fault displacement hazard, the concern lies with those seismogenic structures close to the site that have a potential for displacement at or near the ground surface (that is, capable faults; see Section 8).

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Construction of a regional seismotectonic model

IDENTIFICATION

4.17 The identification of seismogenic structures is made on the basis of geological, geophysical and seismological data providing direct or indirect evidence that these structures have been the source of earthquakes under current tectonic conditions.

The correlation of historical and instrumental recordings of earthquakes with geological and geophysical features is particularly important in identifying seismogenic structures. A lack of correlation does not necessarily indicate that a structure is not seismogenic.

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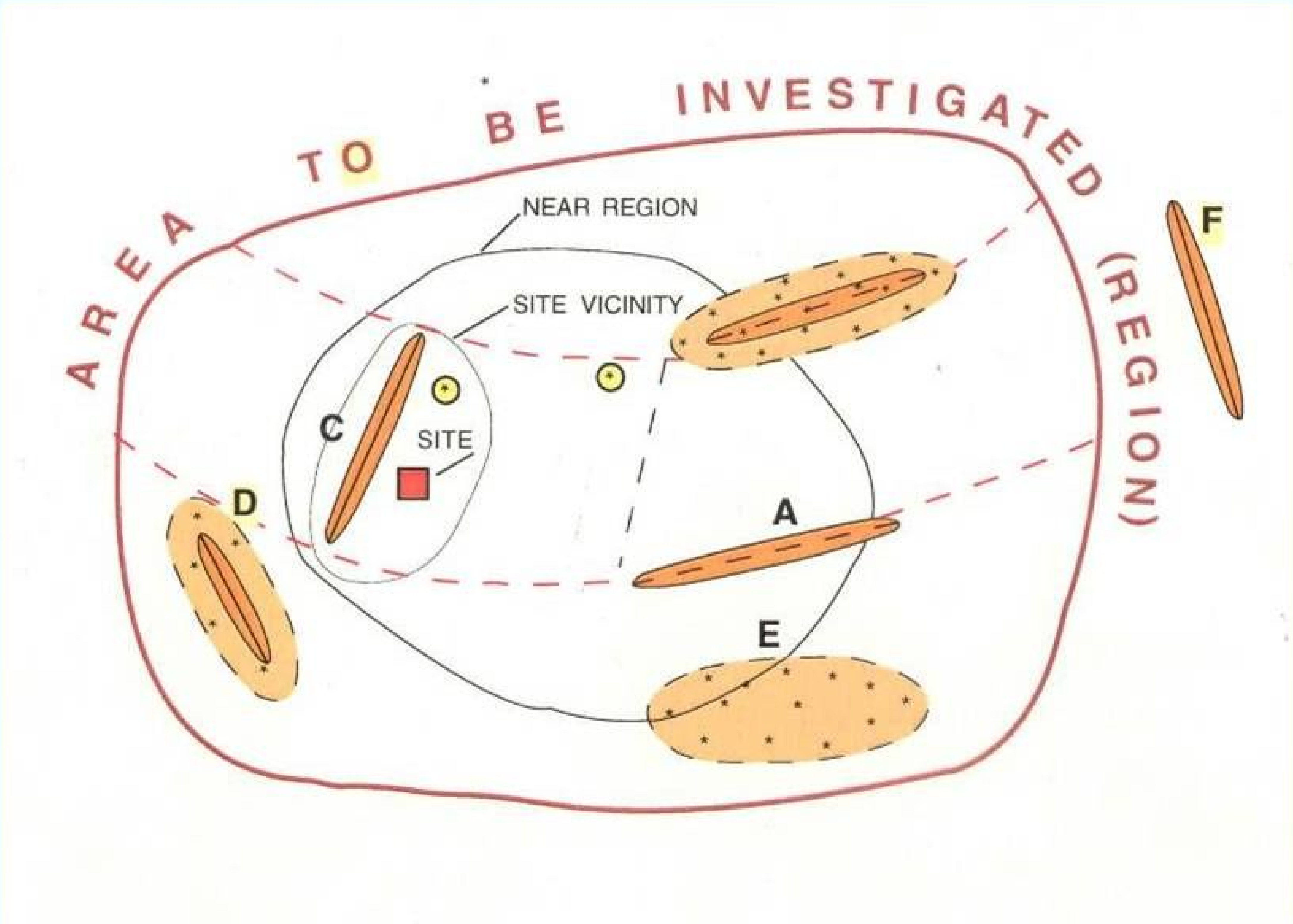
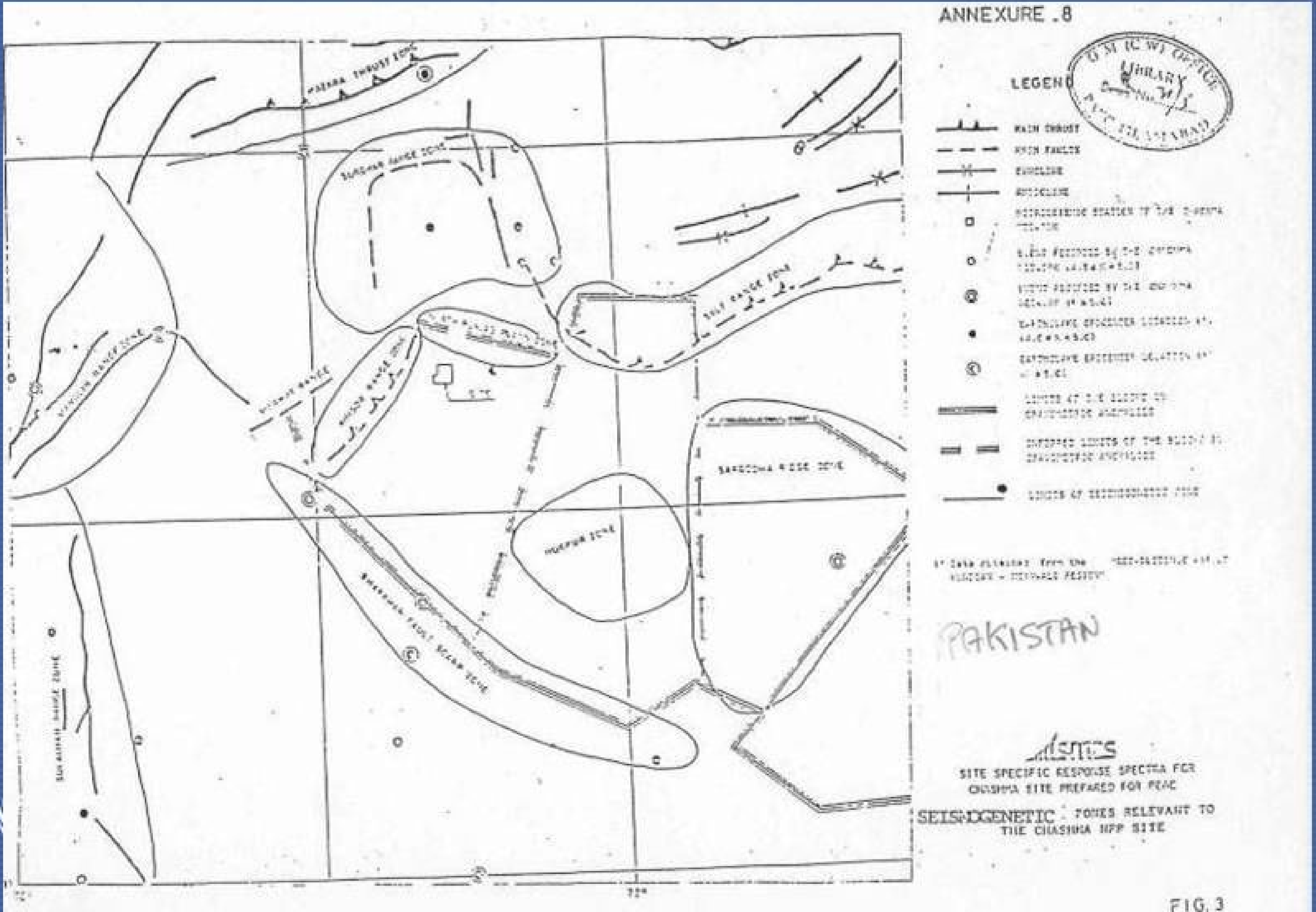
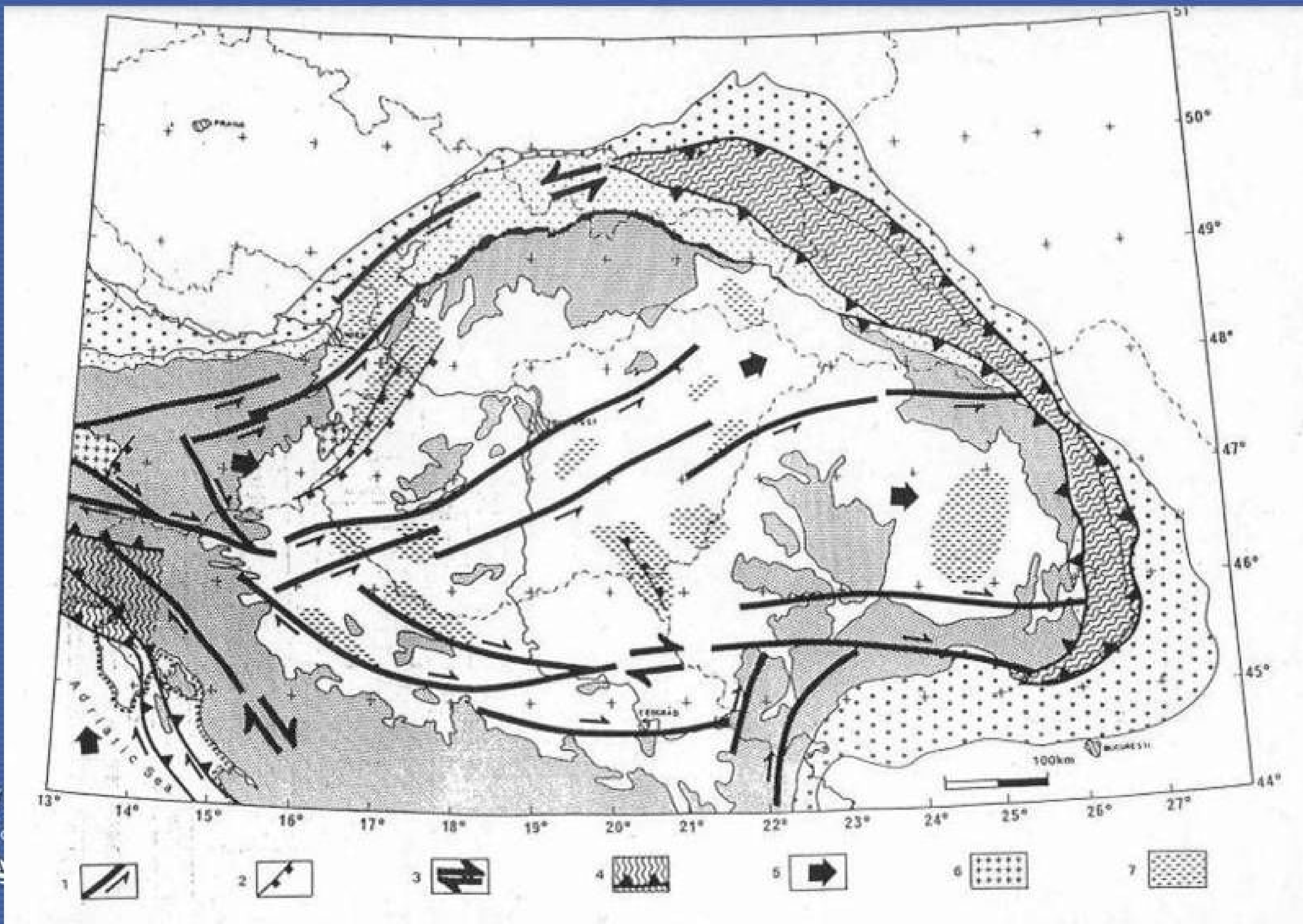
Construction of a regional seismotectonic model



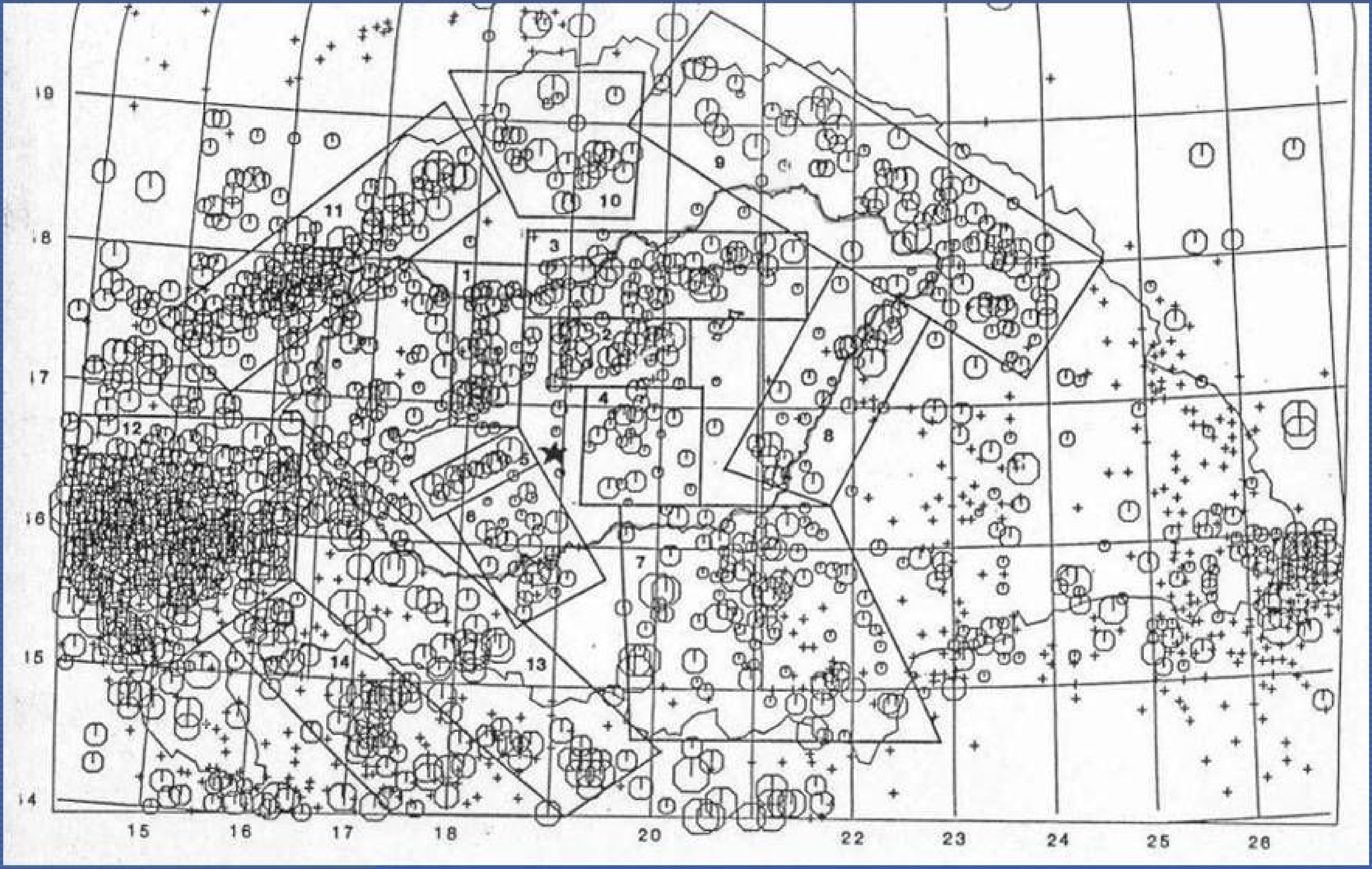
Construction of a regional seismotectonic model



Construction of a regional seismotectonic model: Pannonian Basin

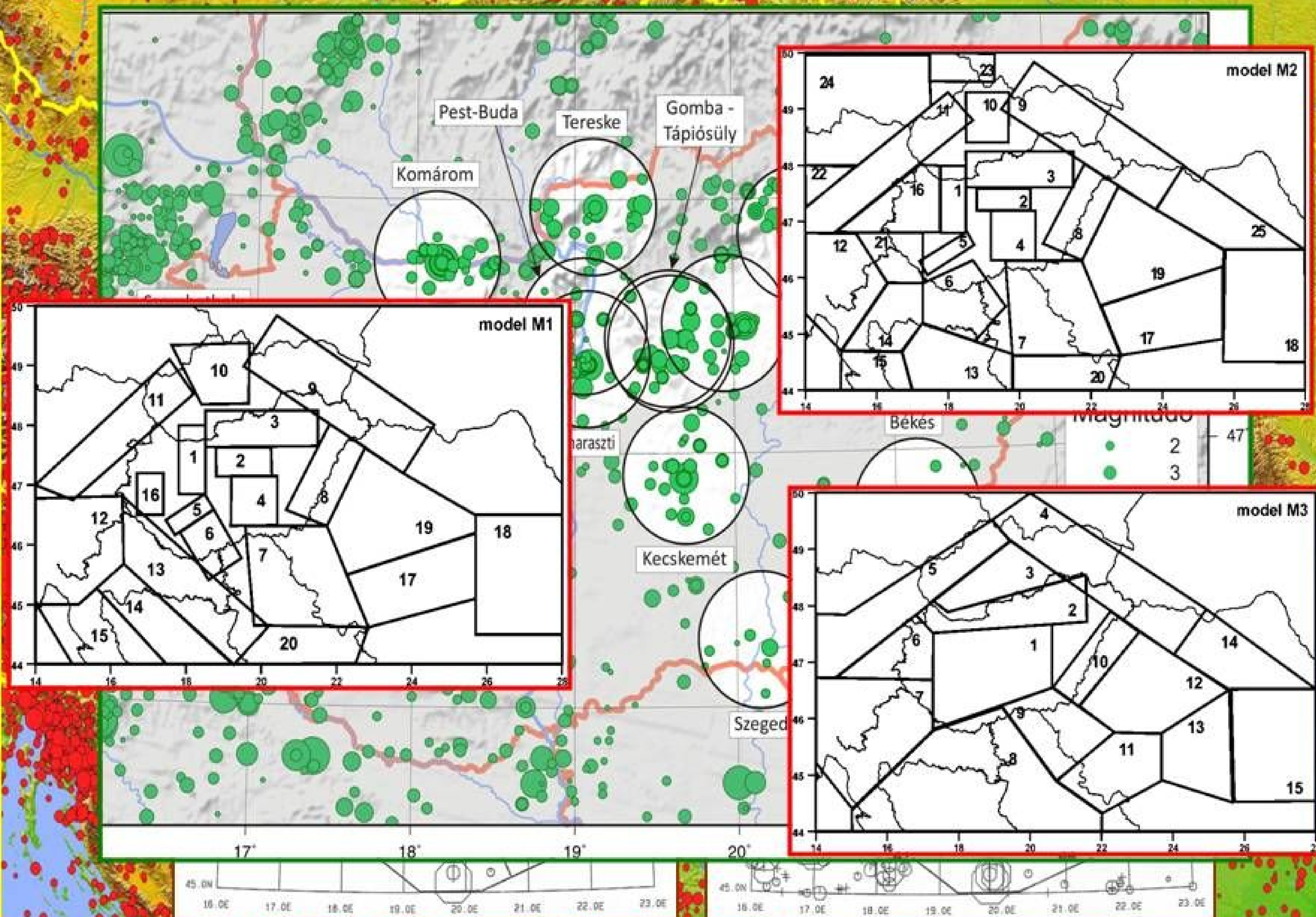


Construction of a regional seismotectonic model: Pannonian Basin

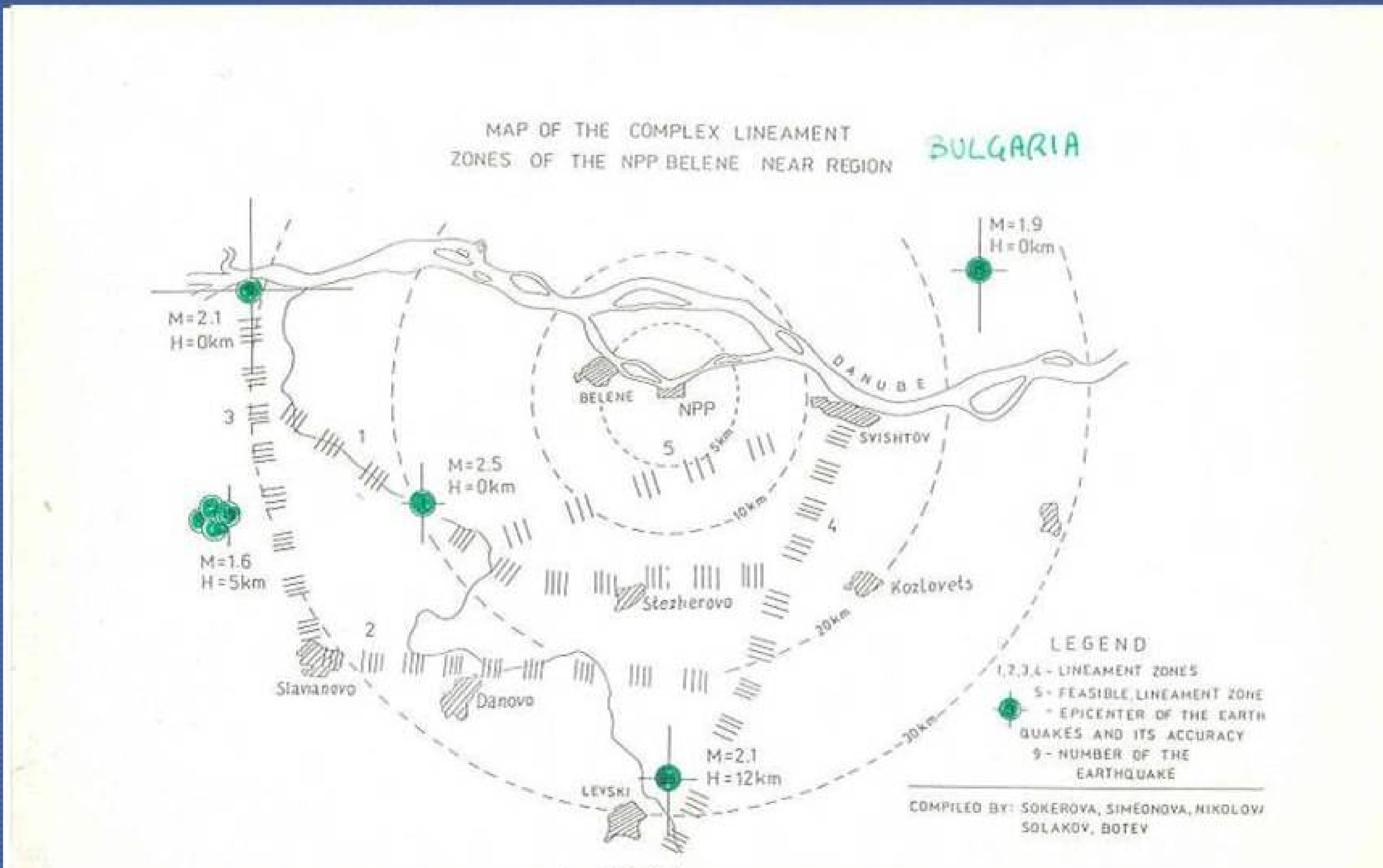


Evaluation of seismic sources

Lack of knowledge -- Significant epistemic uncertainty



Construction of a regional seismotectonic model



Construction of a regional seismotectonic model

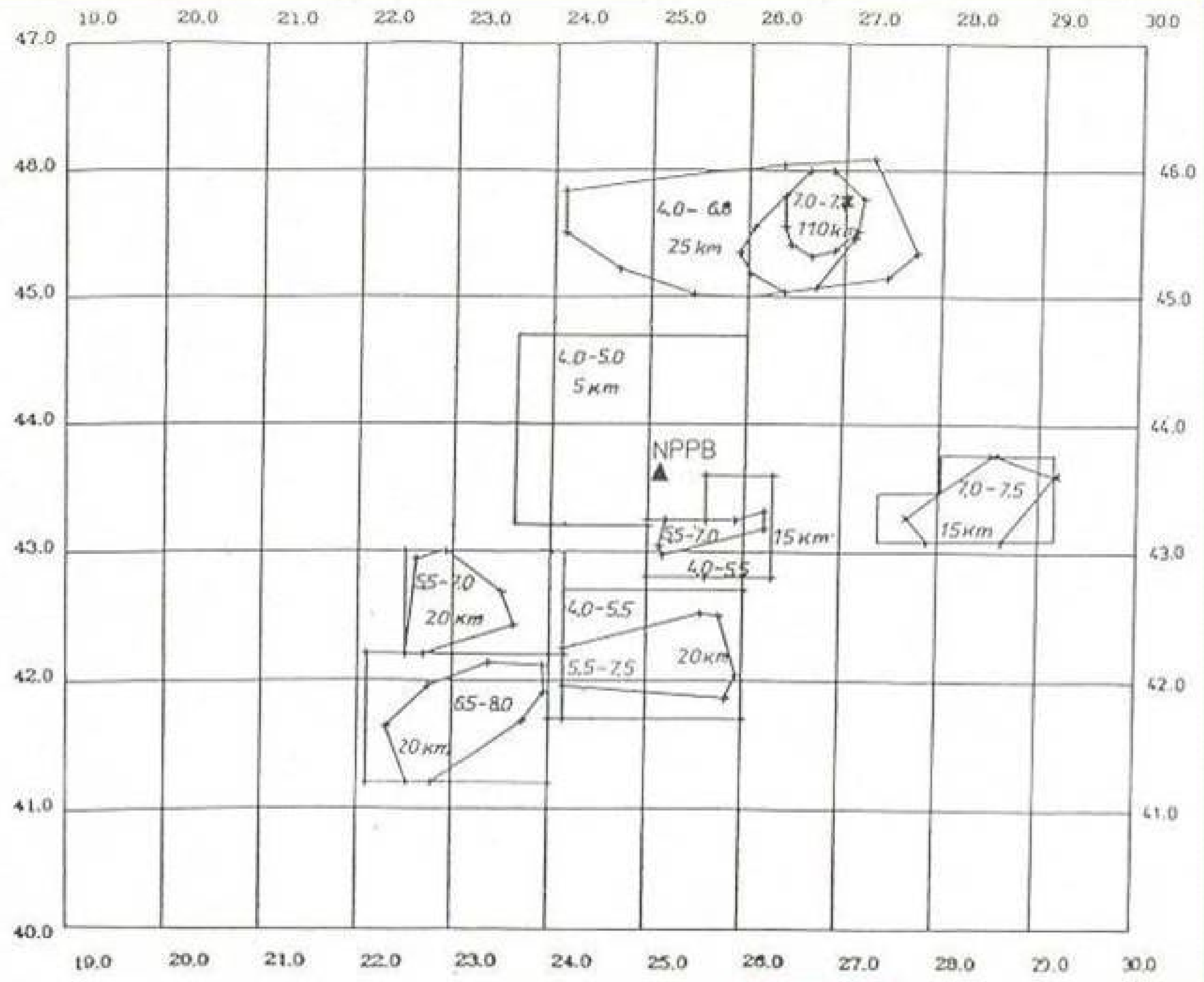


FIG. 4.1. BULGARIA

Construction of a regional seismotectonic model

SEISMOLOGICAL DATA AND SEISMOGENIC STRUCTURES

Whenever the investigations show that an earthquake hypocentre or a group of earthquake hypocentres can be potentially associated with a geological feature, the rationale for the association should be developed by considering the characteristics of the feature, its geometry and geographical extent, and its structural relationship to the regional tectonic framework.

Other available seismological information, such as hypocentral uncertainties, focal mechanisms, stress environments and fore-shock and aftershock distributions, should also be used in considering any association of earthquake hypocentres with geological features.

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Construction of a regional seismotectonic model

COMPARISON WITH OTHER GEOLOGICAL FEATURES

When specific data are lacking or sparse, detailed comparison of any given geological feature with other features in the region in terms of their age of origin, sense of movement and history of movement is essential.

The incorporation of seismogenic structures into a seismotectonic model should be firmly based on the available data and should incorporate uncertainties in the definition of these structures.

Unsupported assumptions as to associations between earthquakes and geological features should not be considered an appropriate assessment of uncertainty, particularly when the geological feature in question is distant from the site.

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Construction of a regional seismotectonic model

CHARACTERIZATION

For seismogenic structures that have been identified to be pertinent to determining the exposure of the site to earthquake hazards the associated characteristics should be determined.

The dimensions of the structure, amount and direction of displacement, maximum historical earthquake, palaeoseismological data, earthquake data and comparisons with similar structures for which historical data are available should be used in this determination.

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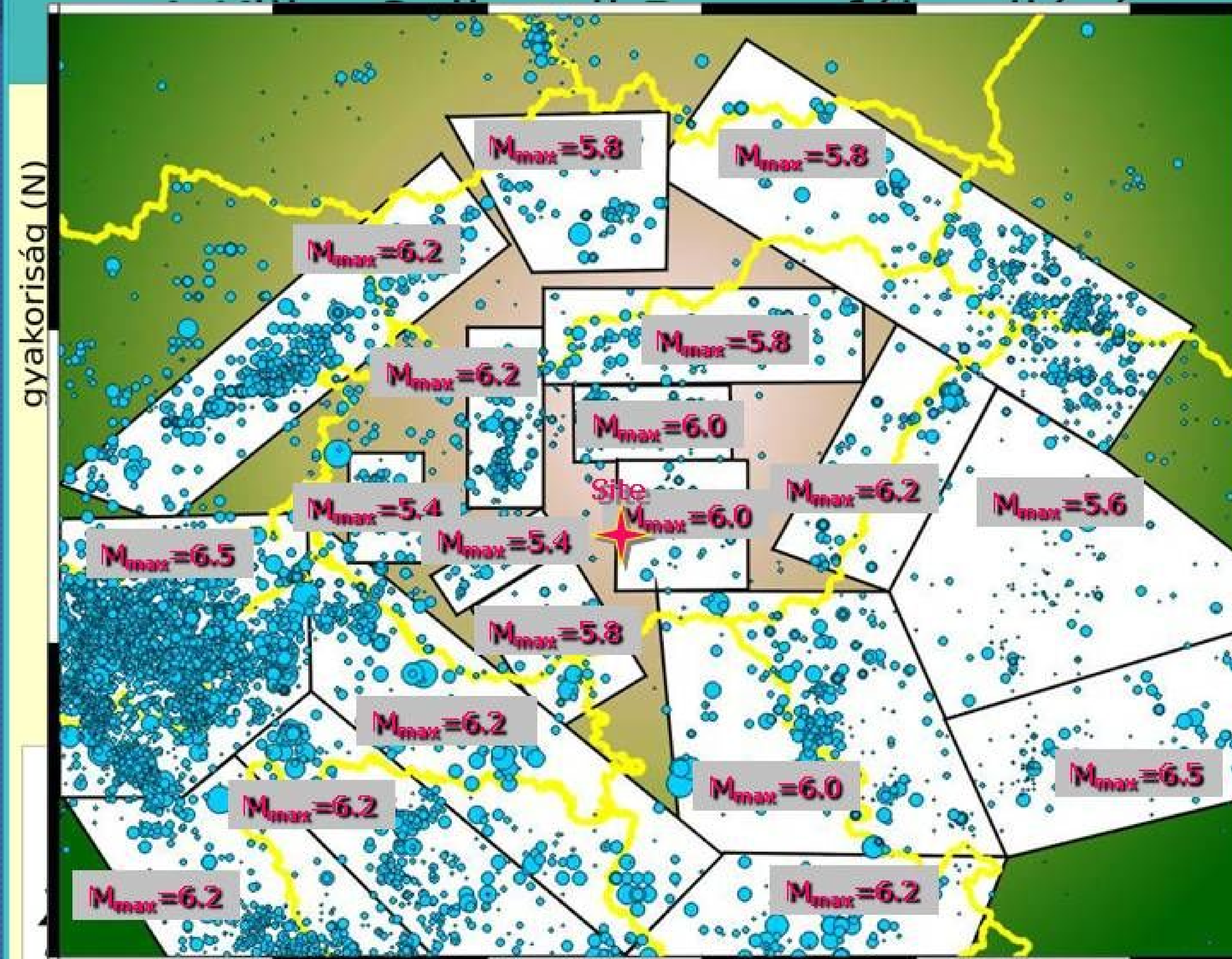
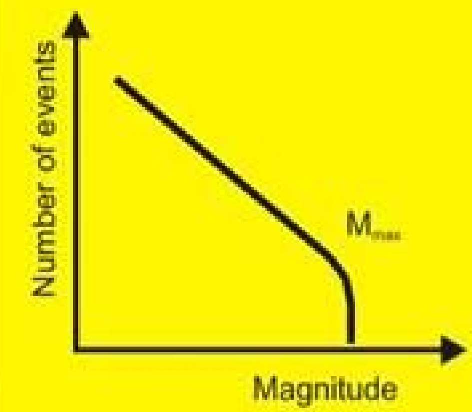
Characterization of seismic sources

Characterization of seismic sources



Source Parameters

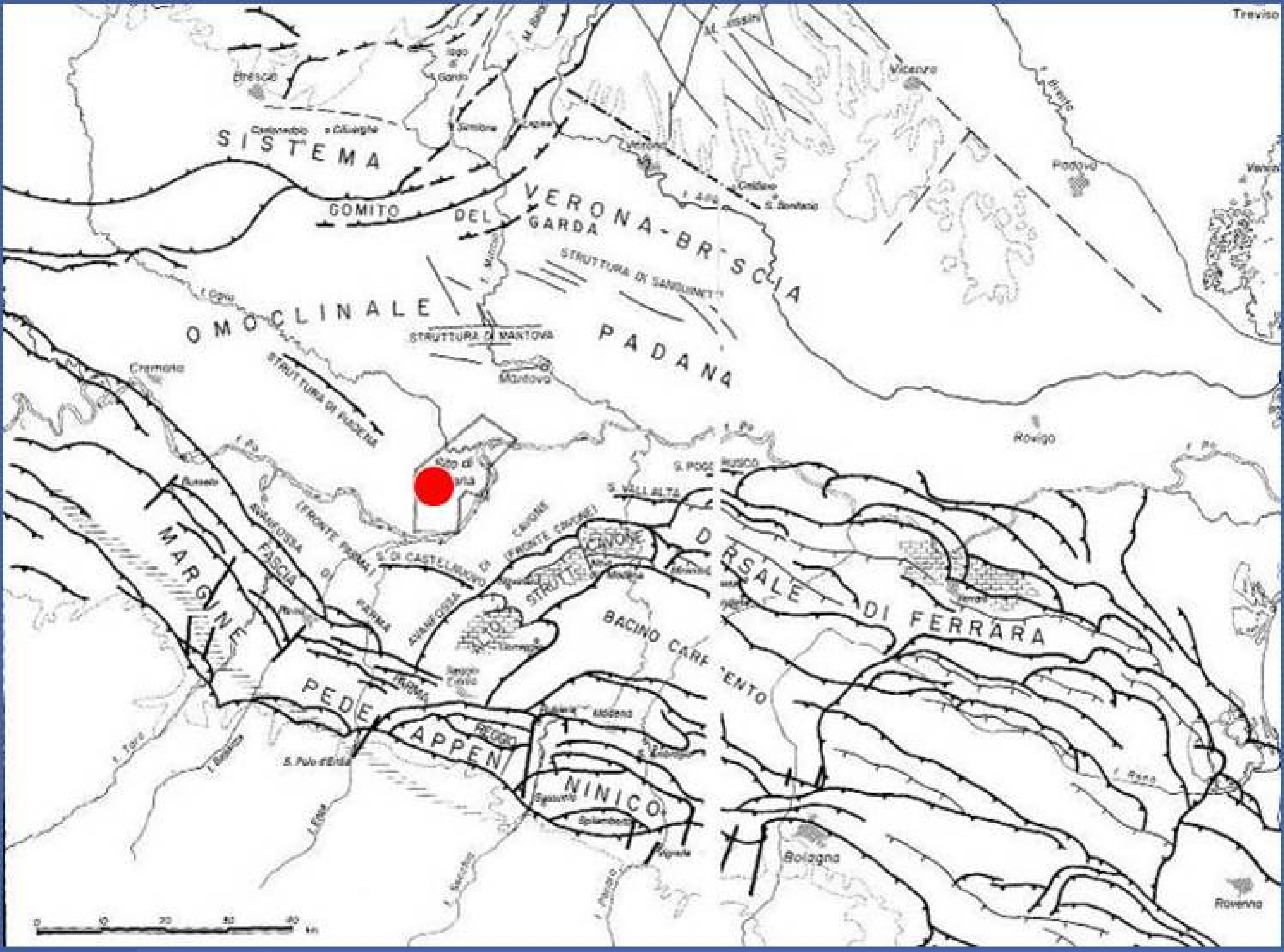
earthquake recurrence
maximum magnitude, M_{max}
hypocentral depth



Construction of a regional seismotectonic model

Viadana (Northern Italy):

regional investigations



Construction of a regional seismotectonic model

TABELLA 1

TABELLA RIASSUNTIVA PER LA DEFINIZIONE DEL TERREMOTO DI RIFERIMENTO PER IL SITO DI VIADANA

	CARATTERI SISMICI DELLE STRUTTURE					CARATTERI SISMICI AL SITO		
Strutture sismogenetiche rilevanti	Imax epic. storica (MCS)	Imax epic. potenziale (MCS)	Campi macrosismici di riferimento (terremoti)	Profondità ipoc. max e più gravoso ril.energia (km)	Magnitudo potenziale (sec. Karnik) (*)	Imax storica (MCS)	Imax epic. potenziale (MCS)	Distanza min. Imax potenziale (km)
Margine pedealpino (o Sistema Verona-Brescia)	IX-X (1117) IX-X (1222)	X	1117 1222	10	6,8	VII (1117) VII (1222)	VIII	50
Margine pedeappenninico (Fascia sismotettonica di Parma-Reggio Emilia)	VIII (1438) VIII (1547) VII-VIII (1832)	IX	1832 1971	15	6,3	VII p.p. (1832) VII p.p. (1971)	VIII	30
avanfossa e alto strutturale di Cavone	VII-VIII (1832) VII (1806) VII (1810) VII (1928)	VIII	1806	8 - 10	5,3	VII p.p. (1806) VII p.p. (1832)	VIII	15
Sito di Viadana	terremoto near - field: M = 4.3					VII	VII	5

* M = 0,66 Io + 1,4 log h - 1,25

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Construction of a regional seismotectonic model

POTENTIAL MAXIMUM MAGNITUDE (1)

When sufficient information about the seismological and geological history of the movement of a fault or structure is available to allow estimates to be made of the maximum rupture dimensions and/or displacements of future earthquakes, direct empirical relationships can be used for evaluating the potential maximum magnitude.

In the absence of suitably detailed data, the potential maximum magnitude of a seismogenic structure can be estimated from its total dimensions. However, to use this approach, a fraction of the total length of the structure which can move in a single earthquake should be used, depending on the characteristics of the fault, in particular on its segmentation.

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Construction of a regional seismotectonic model

POTENTIAL MAXIMUM MAGNITUDE (2)

Other approaches are available for estimating potential maximum magnitudes on the basis of statistical analysis of the magnitude–frequency recurrence relationships for earthquakes associated with a particular structure.

These approaches assume an association between the structure and all the earthquake data used.

In all cases the results of these methods should be consistent with the derived data.

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Construction of a regional seismotectonic model

EQN	Location	Earthquake	Date (UTC, m/d/yr)	Slip Type**	M_S†	M††	Seismic Moment‡ (10^{25} dyne-cm)	Rupture Length (km)†† Surface	Rupture Length (km)†† Subsurface	Rupture Width†† (km)	Rupture Area†† (km²)	Displacement (m)†† Maximum	Displacement (m)†† Average
1	USA, CA	Fort Tejon	01/09/1857	RL	8.3 [I]	(7.85)	670 [1]	297		12‡‡	(4296)	9.4	6.4#
2	USA, CA	Hayward	10/21/1868	RL	6.8 [I]	(6.76)	15.6 [1]	48		12‡‡	(576)	0.9	
3	USA, CA	Owens Valley	03/26/1872	RL-N	8.0 [I]	(7.61)	292 [1]	108		15‡‡	(1620)	11.0	6.0
4	Mexico	Pitaycachi	05/03/1887	N	7.4 [I]	(7.31)	105 [1]	75				4.5	1.9
5	Japan	Nobi	10/27/1891	LL	8.0 [I]	(7.49)	190 [1]	80		15‡‡	(1200)	8.0	5.04#
6	Japan	Rikuu/Senya	08/31/1896	R	7.2 [J]	(7.40)	140 [1]	40		(21)‡‡	(840)	4.4	2.59#
7	USA, CA	San Francisco	04/18/1906	RL	7.8 [B]	7.90	790 [5]	432		12‡‡	5184	6.1	3.3#
8	Italy	Avezzano	01/13/1915	N	7.0 [G]	(6.62)	9.7 [2]	20	24¶	15¶	360¶	2.0	
9	USA, Nevada	Pleasant Valley	10/03/1915	N	7.6 [L]	(7.18)	66 [1]	62		15‡‡	(930)	5.8	2.0
10	China	Kansu	12/16/1920	LL	8.5 [G]	8.02	1200 [3]	220		(20)‡‡	(4400)	10.0	7.25#
11	Japan	Tango	03/07/1927	LL-R	7.7 [L]	(7.08)	46 [1]	(14)	(35)	15	525	(3.0)	
12	Kenya	Laikipia	01/06/1928	N	7.0 [L]			31				3.3	
13	Bulgaria	Papazili	04/18/1928	N	6.9 [L]	(7.13)	55 [1]	50				3.5	
14	Iran	Salmas	05/06/1930	N-RL	7.4 [L]	(7.15)	60 [1]	30				6.4	1.35
15	Japan	North Izu	11/25/1930	LL-R	7.3 [L]	6.89	24 [5]	35	(22)¶	(12)‡‡	(420)	3.8	2.9
16	New Zealand	Hawkes Bay	02/02/1931	R-RL	7.8 [G]	(7.73)	440 [2]	15	(110)			(4.6)	
17	China	Kehetuohai-E	08/10/1931	RL	7.9 [L]	7.92	850 [3]	180		(20)‡‡	(3600)	14.6	7.38#
18	Japan	Saitama	09/21/1931	LL	6.7 [G]	(6.52)	6.8 [1]		20	10	200		
19	USA, Nevada	Cedar Mountain	12/21/1932	RL	7.2 [G]	6.83	19.7 [3]	61	(80)			2.0	
20	China	Changma	12/25/1932	R-LL	7.7 [L]	(7.60)	280 [1]	148				4.0	2.0
21	USA, CA	Long Beach	03/11/1933	RL	6.3 [G]	6.38	4.1 [5]		23	13	300		
22	Japan	South Izu	03/21/1934	RL	5.5 [J]	(5.29)	0.095 [1]		7§	4	28§		
23	Taiwan	Tuntzuchio/Chih.	04/21/1935	RL-R	7.1 [G]			(17)				2.1	
24	Turkey	Kirsehir	04/19/1938	RL	6.8 [L]			14				1.0	
25	Turkey	Erzihcan	12/26/1939	RL	7.8 [L]	(7.81)	575 [1]	360		(20)‡‡	(7200)	7.5	(1.85)

Wells & Coppersmith (1994) – database 421 earthquakes

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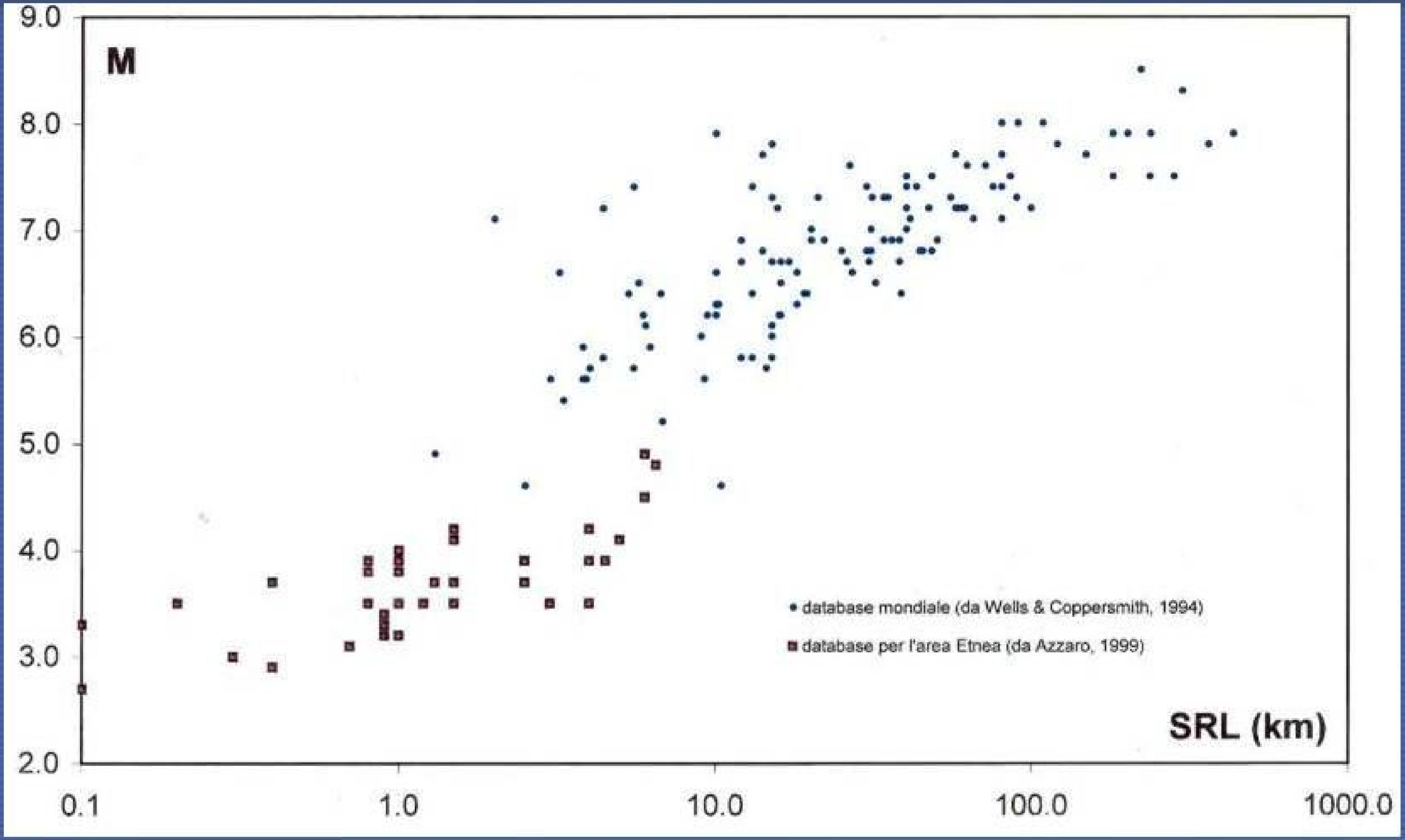
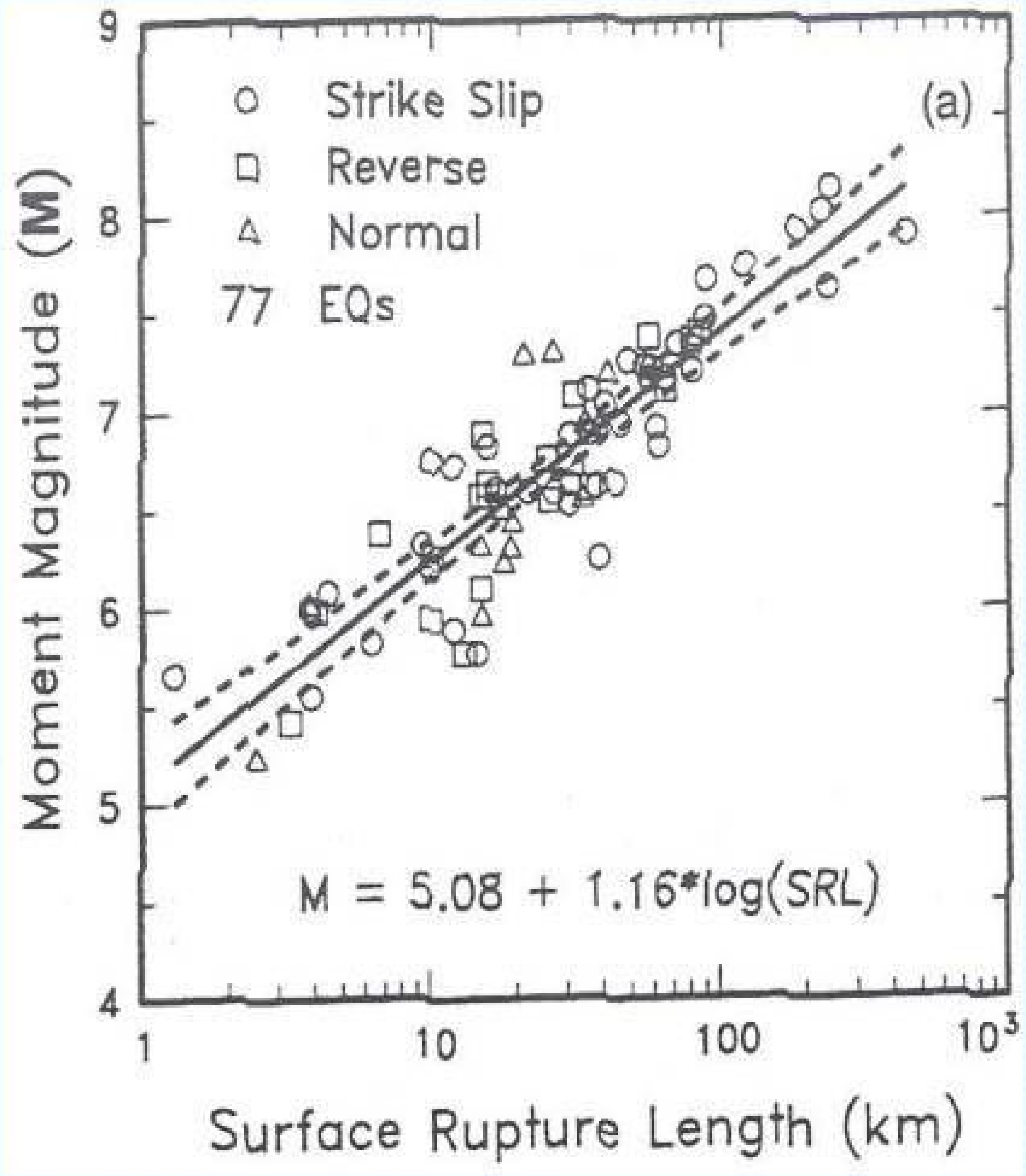
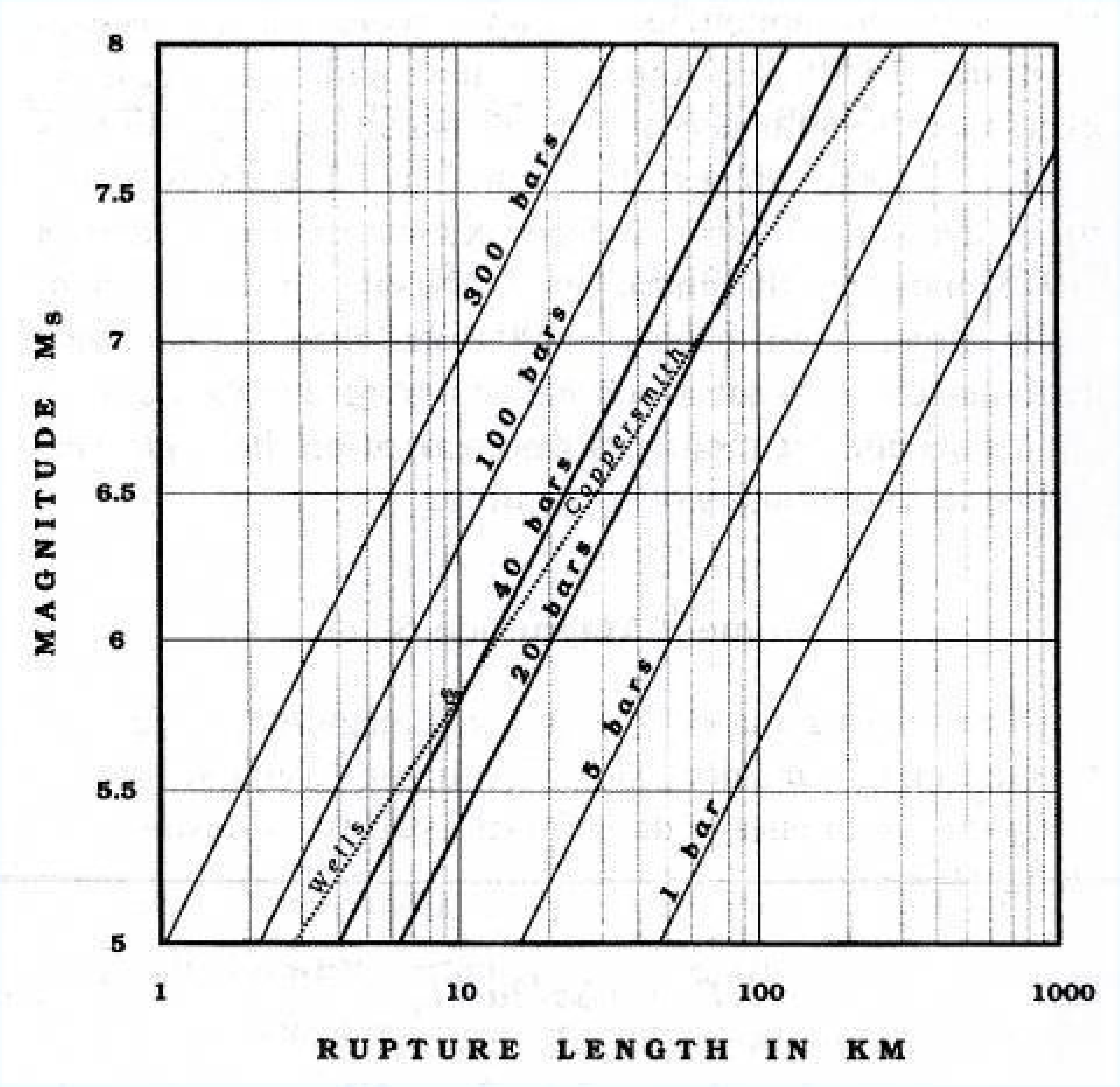
Construction of a regional seismotectonic model



Construction of a regional seismotectonic model

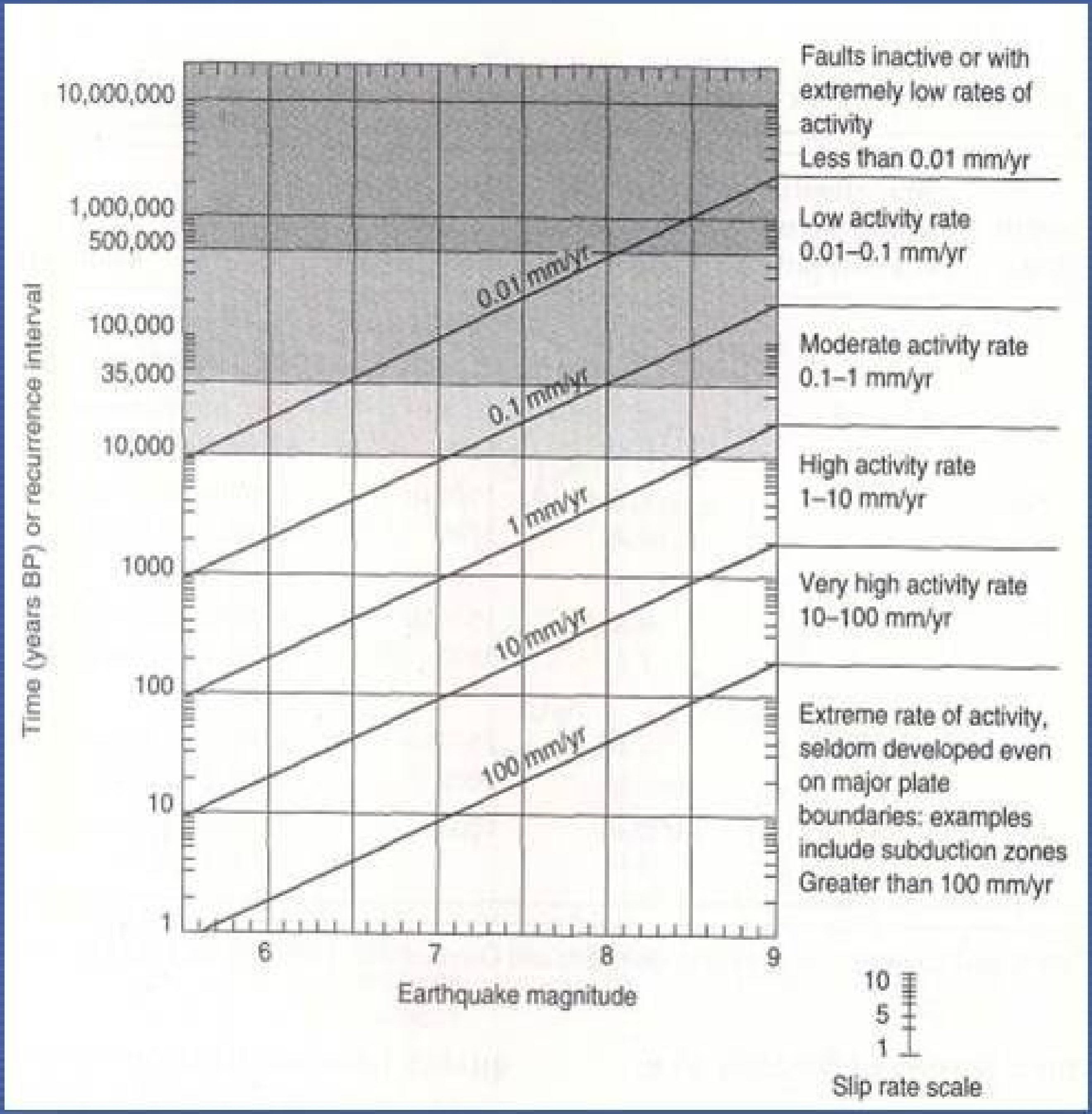


Wells & Coppersmith (1994)



Mohammadioun & Serva (2001)

Construction of a regional seismotectonic model



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Slemmons & de Polo (1986)

Construction of a regional seismotectonic model

ZONES OF DIFFUSE SEISMICITY

Seismotectonic provinces may be defined in a seismotectonic model to represent diffuse seismicity for the purpose of seismic hazard evaluation, with each seismotectonic province being assumed to encompass an area having equal seismic potential..

Estimates about the maximum depth of foci can be made based on the fact that earthquakes are originated in the brittle to ductile transition zone of the crust.

Significant differences in rates of seismicity may suggest different tectonic conditions and may be used in defining boundaries.

Significant differences in hypocentral depth (for example, crustal versus deeper) may be used to differentiate between zones.

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Construction of a regional seismotectonic model

CHARACTERIZATION OF DIFFUSE SEISMICITY

The maximum potential earthquake not associated with identified seismogenic structures should be evaluated on the basis of historical data and the seismotectonic characteristics of the zone.

Comparison with similar regions for which extensive historical data are available may be useful, but considerable judgement should be used in the evaluation.

Often this value will have significant uncertainty owing to the relatively short period covered by historical data with respect to the ongoing tectonism.

This uncertainty should be described by a representative distribution or by assuming an appropriately conservative value, depending on whether a probabilistic or deterministic hazard assessment is used.

Construction of a regional seismotectonic model

DIFFUSE SEISMICITY: EARTHQUAKE RECURRENCE MODEL

Earthquake recurrence should be evaluated for each zone of diffuse seismicity.

This evaluation should include determination of the appropriate earthquake recurrence model and model parameters, and an assessment of the uncertainty in the model and parameters.

The Poisson exponential model is generally more appropriate for zones of diffuse seismicity. For either type of seismic source, however, alternative recurrence models may be used with appropriate weightings to express the evaluator's uncertainty.

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Construction of a regional seismotectonic model

SEISMIC SOURCES IN INTRAPLATE REGIONS

A determination of the rate of earthquake activity for seismic sources that have few earthquakes, as may be encountered in intraplate tectonic regions, may have considerable uncertainty.

For these sources, determination of the slope parameter may include adopting a value that represents the regional tectonic setting of the seismic source, for example, a stable continental tectonic setting.

This approach may be considered viable because the slope parameter (the b value) has been shown to vary only over a narrow range within a tectonic setting. Regardless of the approach used to determine the slope parameter of the recurrence distribution, uncertainty in the parameter should be appropriately assessed and incorporated into the seismic hazard analysis.

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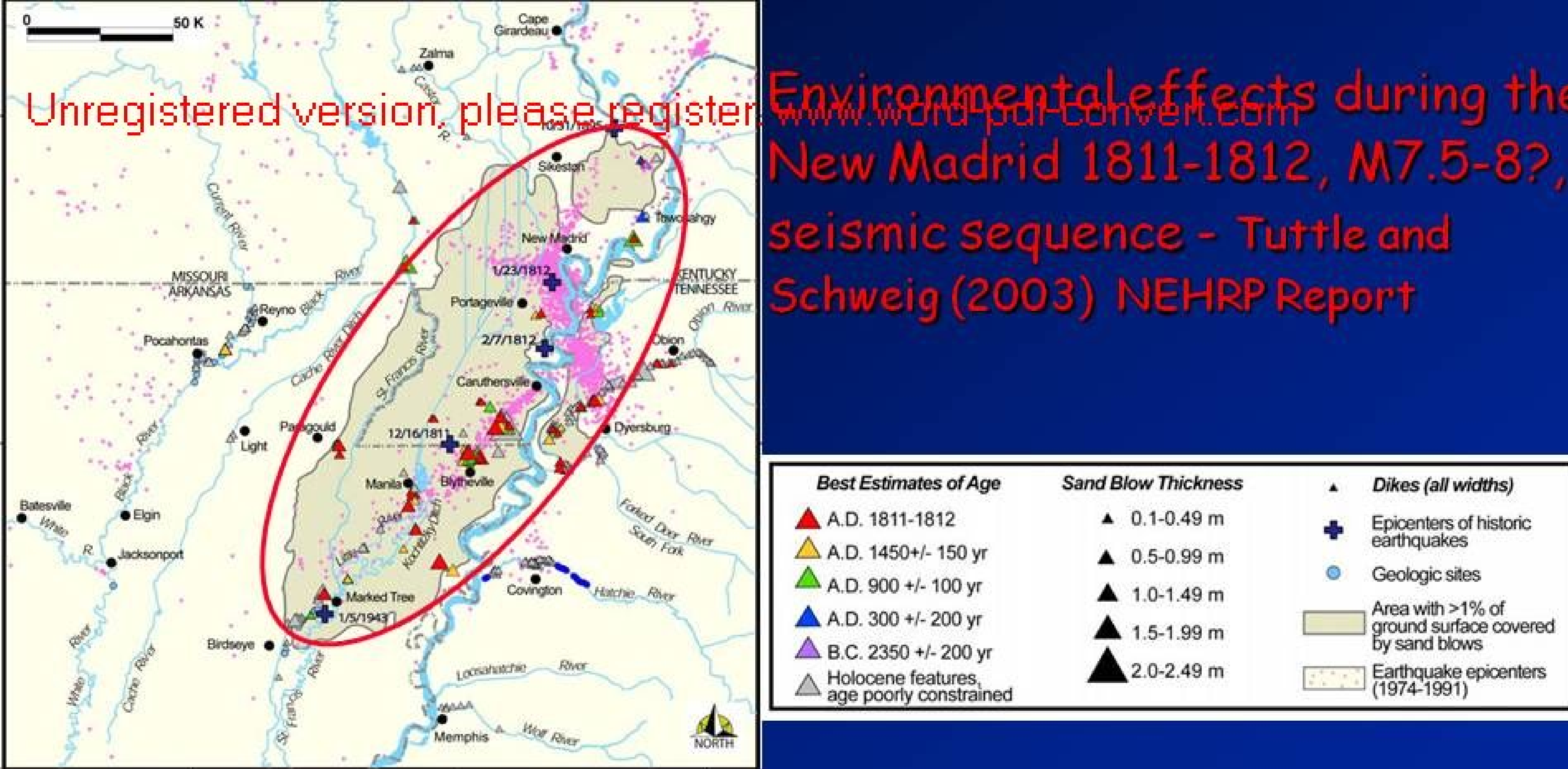
Environmental effects during the New Madrid 1811-1812, M7.5-8?, seismic sequence - Tuttle and Schweig (2003) NEHRP Report



TOTAL AREA OF LIQUEFACTION ca. 20.000 KM^2

ESI = XI

SUMMARY

- Introduction
- Glossary
- Necessary information and investigations (database)
- Construction of a regional seismotectonic model
- Potential for fault displacement at or near the site

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Potential for fault displacement at or near the site

8.3 DEFINITION

The main question with regard to surface faulting is whether a fault (buried or outcropping) at or near the site is capable.

The basis for answering such a question should be the database as incorporated in the seismotectonic model, together with such additional specific data as may be needed.

Firstly it should be taken into consideration that surface faulting may also occur even without being associated with significant releases of seismic energy.

Fault creep has typically been observed in areas characterized by high tectonic activity and seismicity.

Stable sliding, seismic fault ground rupture and seismogenic surface faulting can be considered modes of fault displacement that may occur both in time and in space along capable faults.

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Potential for fault displacement at or near the site

CAPABLE FAULTS

8.4 A fault shall be considered capable:

1) If it shows evidence of past movement or movements (such as significant deformations and/or dislocations) of a recurring nature within such a period that it is reasonable to infer that further movements at or near the surface may occur. In highly active areas, where both earthquake data and geological data consistently reveal short earthquake recurrence intervals, periods of the order of tens of thousands of years (e.g., Upper Pleistocene – Holocene – i.e. present) may be appropriate for the assessment of capable faults. In less active areas, it is likely that much longer periods (e.g.. Pliocene–Quaternary – i.e. present) are appropriate.

2) If a structural relationship with a known capable fault has been demonstrated such that movement of the one fault may cause movement of the other at or near the surface.

3) If the maximum potential earthquake associated with a seismogenic structure is sufficiently large and at such a depth that it is reasonable to infer that, in the geodynamic setting of the plant, movement at or near the surface may occur.

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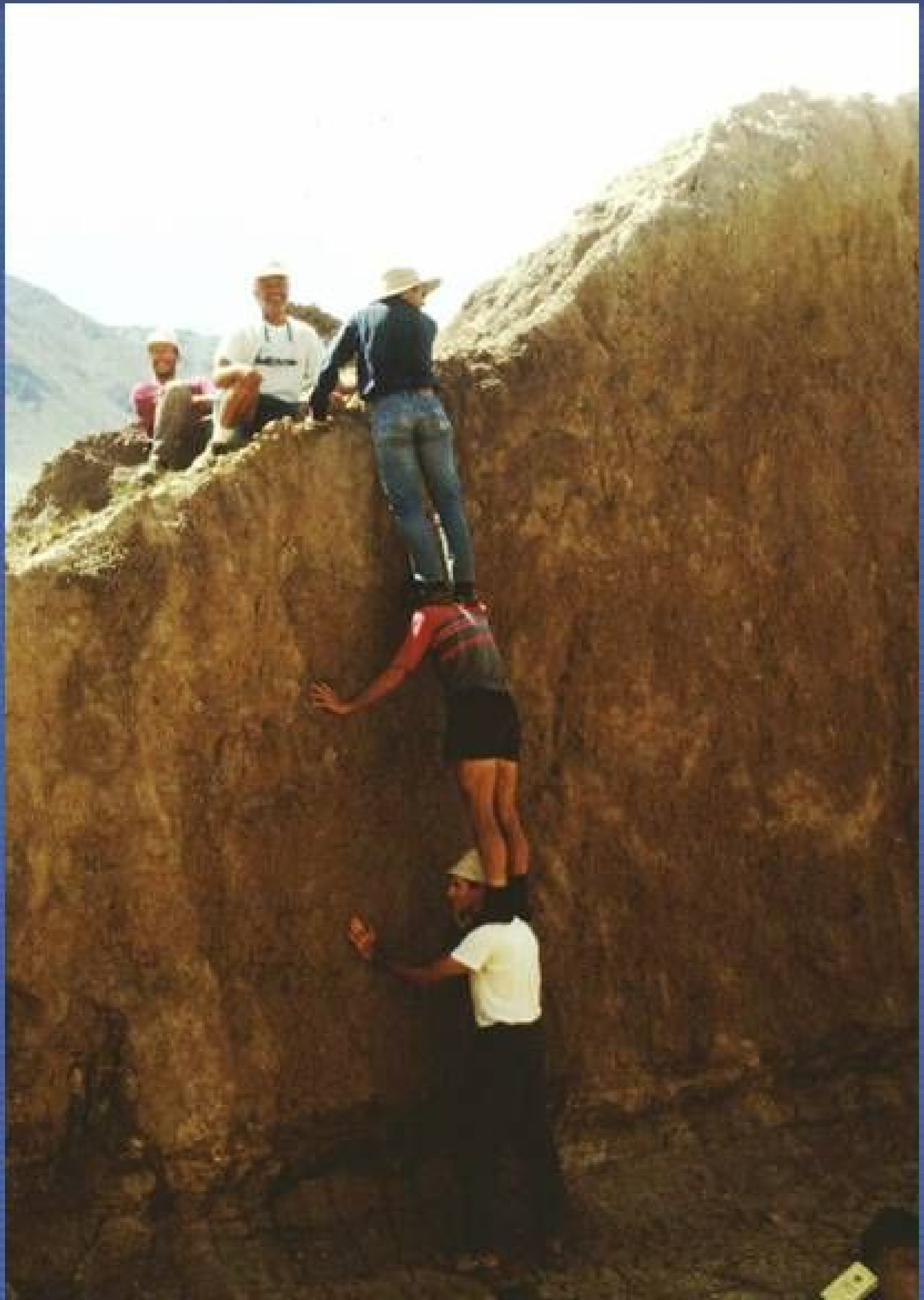
Potential for fault displacement at or near the site

Potential for fault displacement at or near the site

January 3, 1911, Chon Kemin, Kirgyzstan earthquake (Ms 8.2)

Potential for fault displacement at or near the site



December 4, 1957, Mogod, Gobi-Altay earthquake (Mw 8.1).

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Potential for fault displacement at or near the site

September 27, 2003 Altai, Russia earthquake (Ms=7.4)

Chacao Bridge Project – Chile – South America

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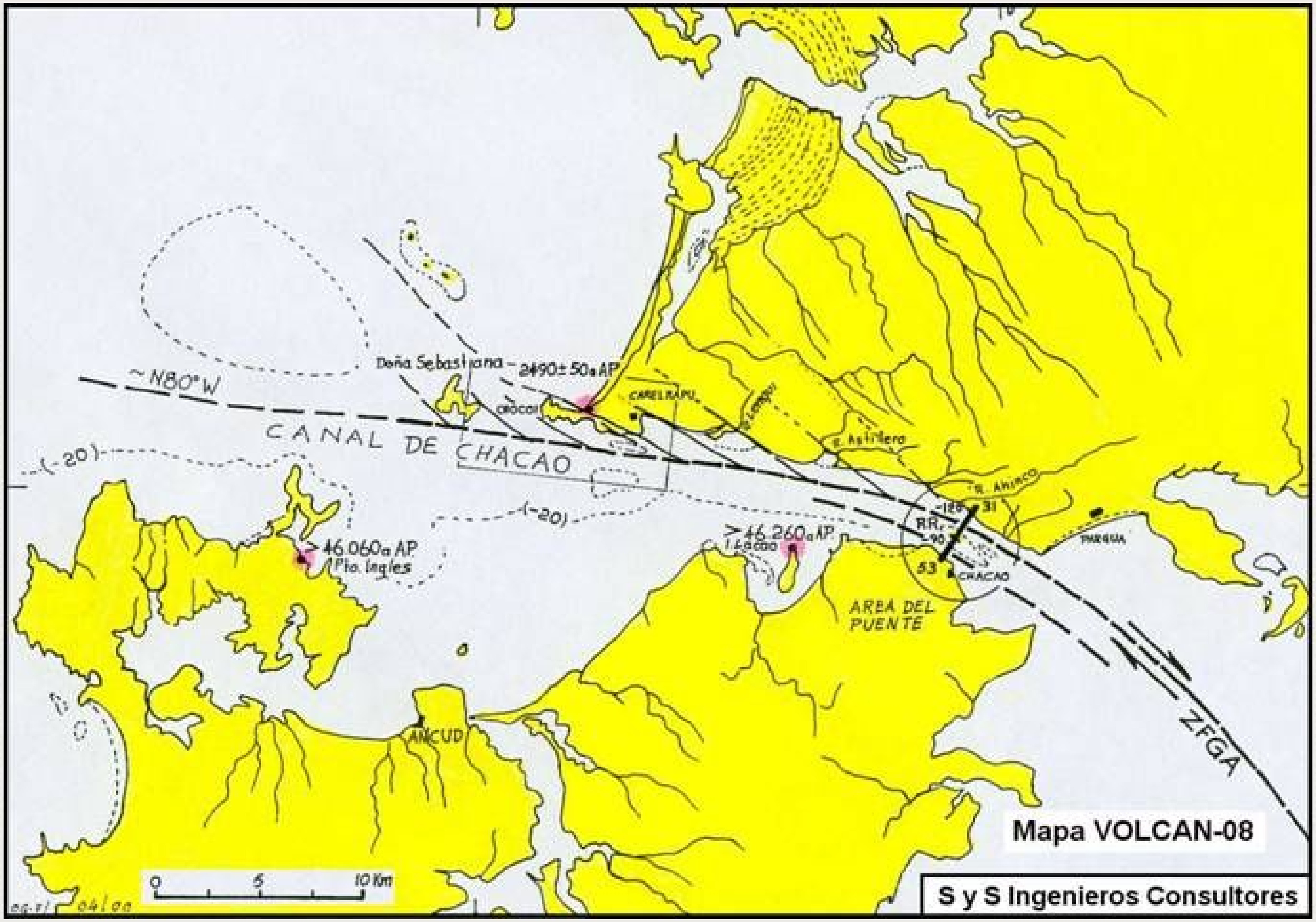
Chacao Bridge Project – Chile – South America



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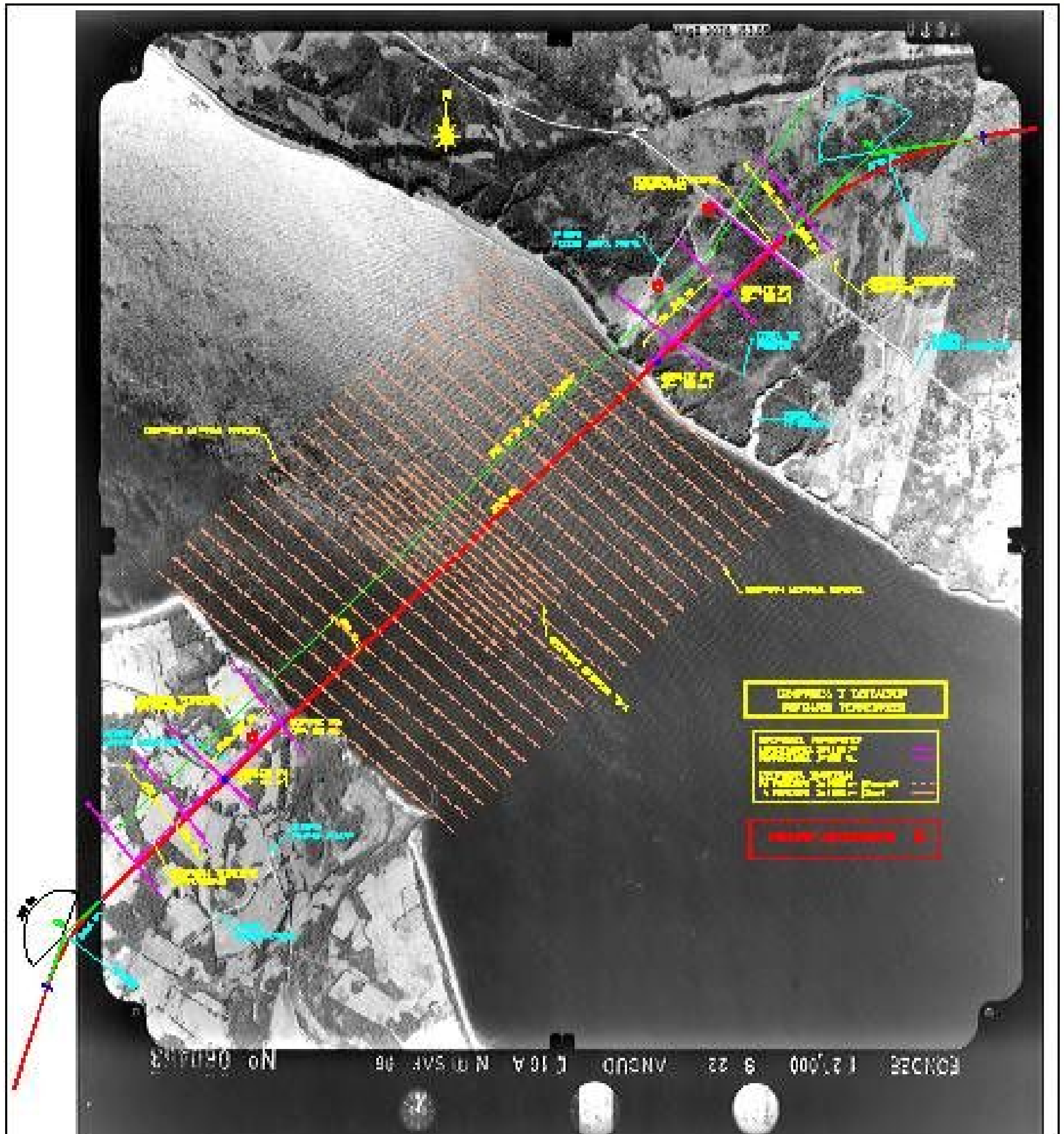
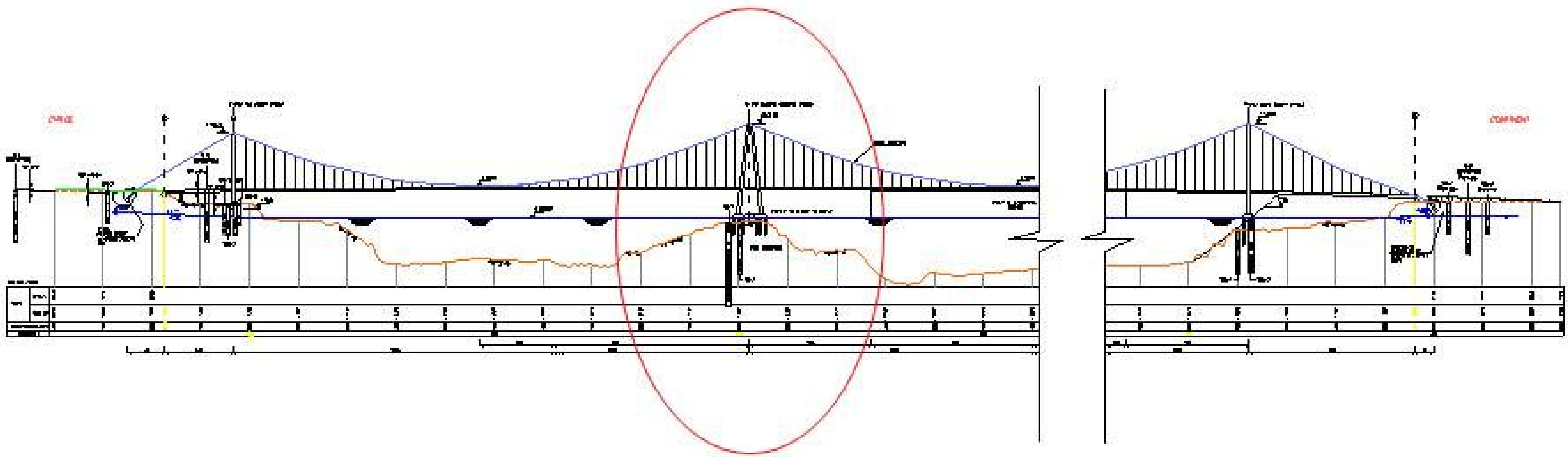
Chacao Bridge Project – Chile – South America

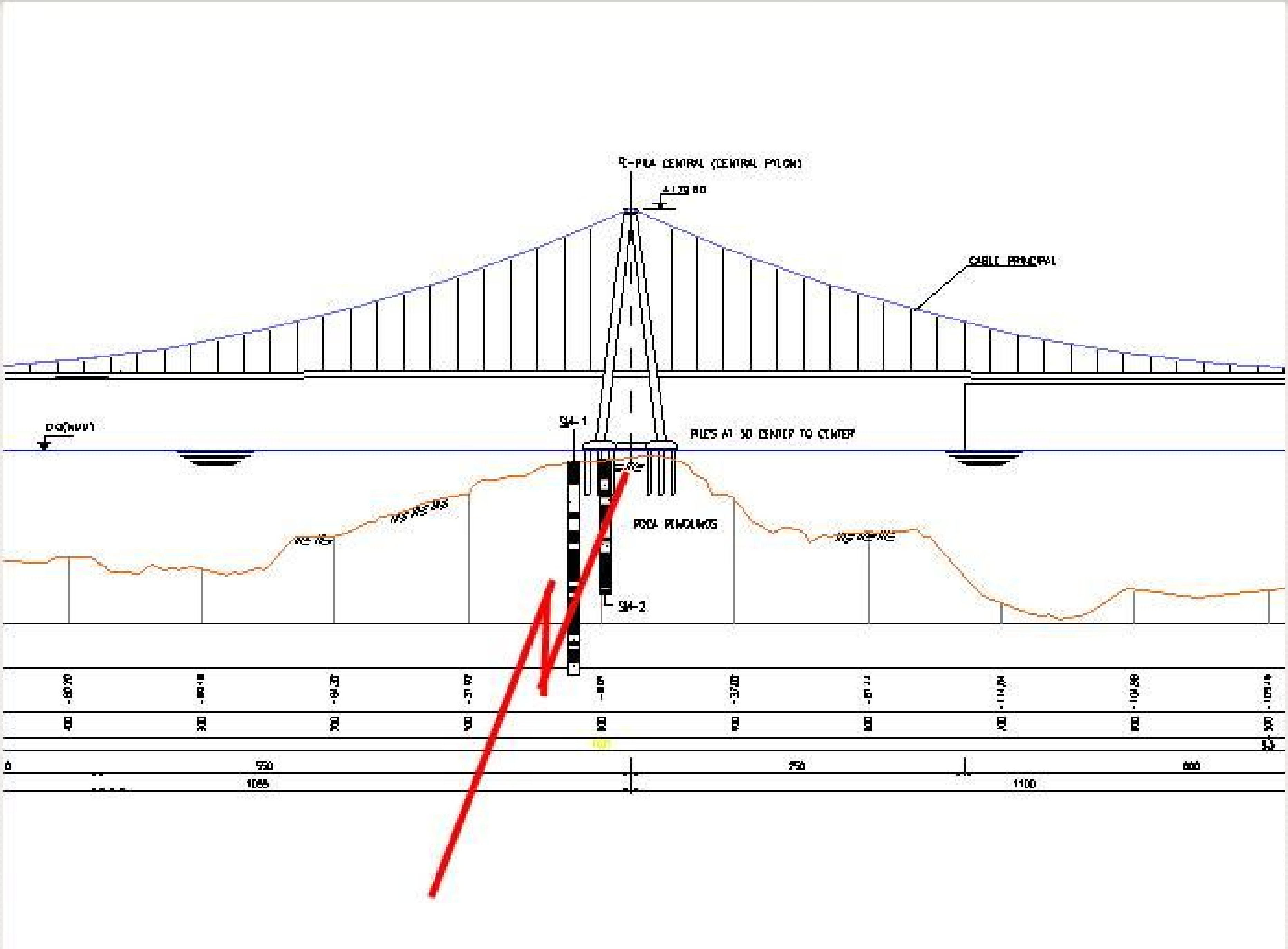


Canal Chacao. Esc Aprox. 1:10.000

Chacao Bridge Project – Chile – South America



Chacao Bridge Project – Chile – South America



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Chi-Chi earthquake, trace of surface rupture (courtesy of Karl Mueller)

Offset of dam on Tachia river - 10 m of vertical slip

M 7.9 Denali fault, Alaska, earthquake of November 3, 2002. Milepost 215.5 on the Richardson Highway. The direction of view is approximately from north to south. The fault trace is running almost NW-SE direction. The horizontal offset is approximately 2-2.5m. Photo courtesy: Akihiko Ito

M 7.9 Denali fault, Alaska, earthquake of November 3, 2002.
Milepost 215.5 on the Richardson Highway
(http://earthquake.usgs.gov/eqinthenews/2002/uslbbl/photos/pr071102/rhnpipeline2.jpg)

Denali crossing of the Trans-Alaska Pipeline route.

(http://earthquake.usgs.gov/eqinthenews/2002/uslbbl/photos/pr071102/new/small/PICT0072.JPG)

NO DAMAGE

GREAT SUCCESS!!!

Potential for fault displacement at or near the site

October 02, 1915 Pleasant Valley, Nevada, USA, earthquake (M = 7.8)

Potential for fault displacement at or near the site

MODIFICATION OF THE LANDSCAPE

↑

EARTHQUAKES

↑

ONE EARTHQUAKE

LANDSCAPE

↓

INTERPRETATION OF EARTHQUAKES THAT HAVE CONTROLLED THE LANDSCAPE EVOLUTION

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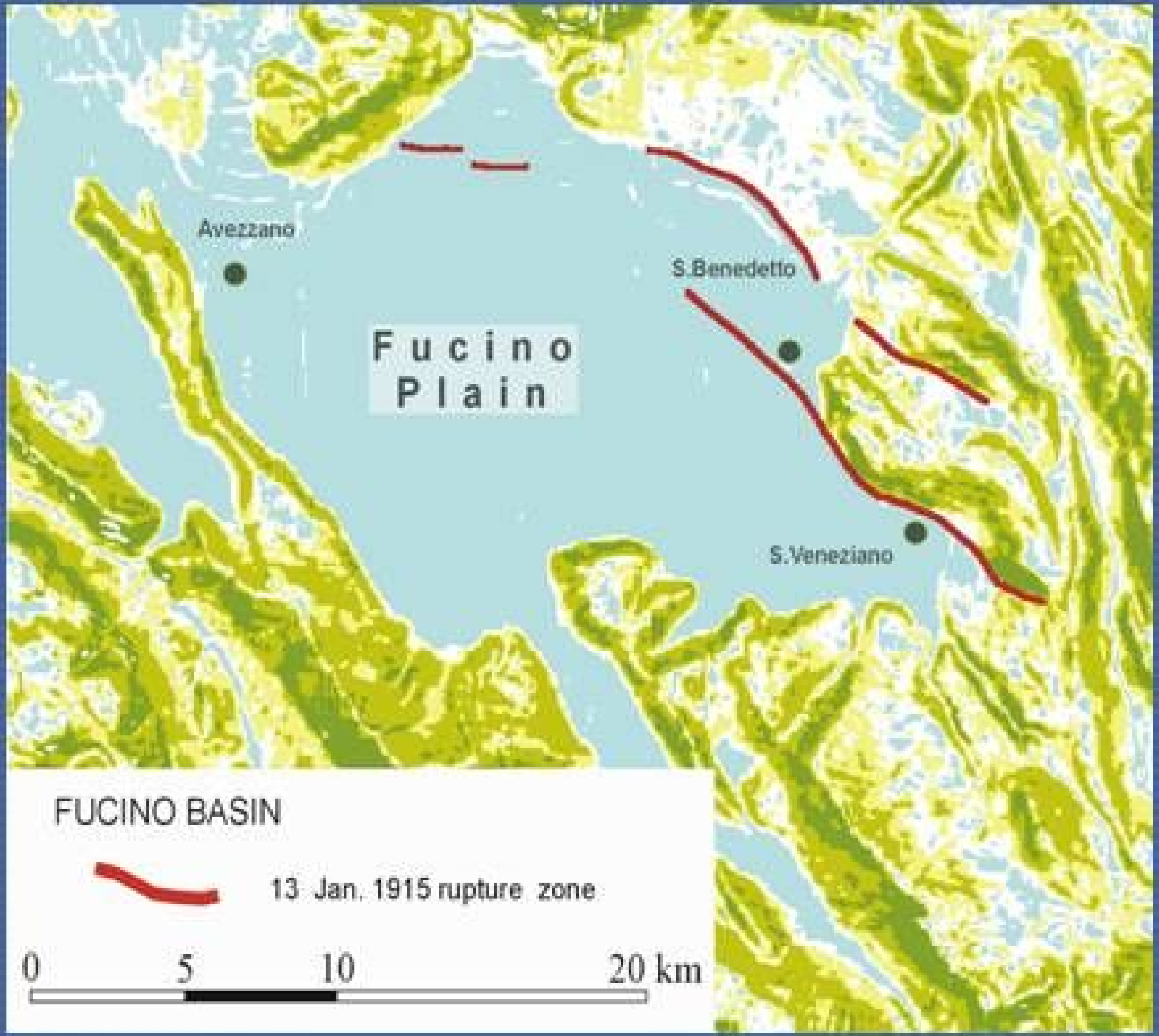
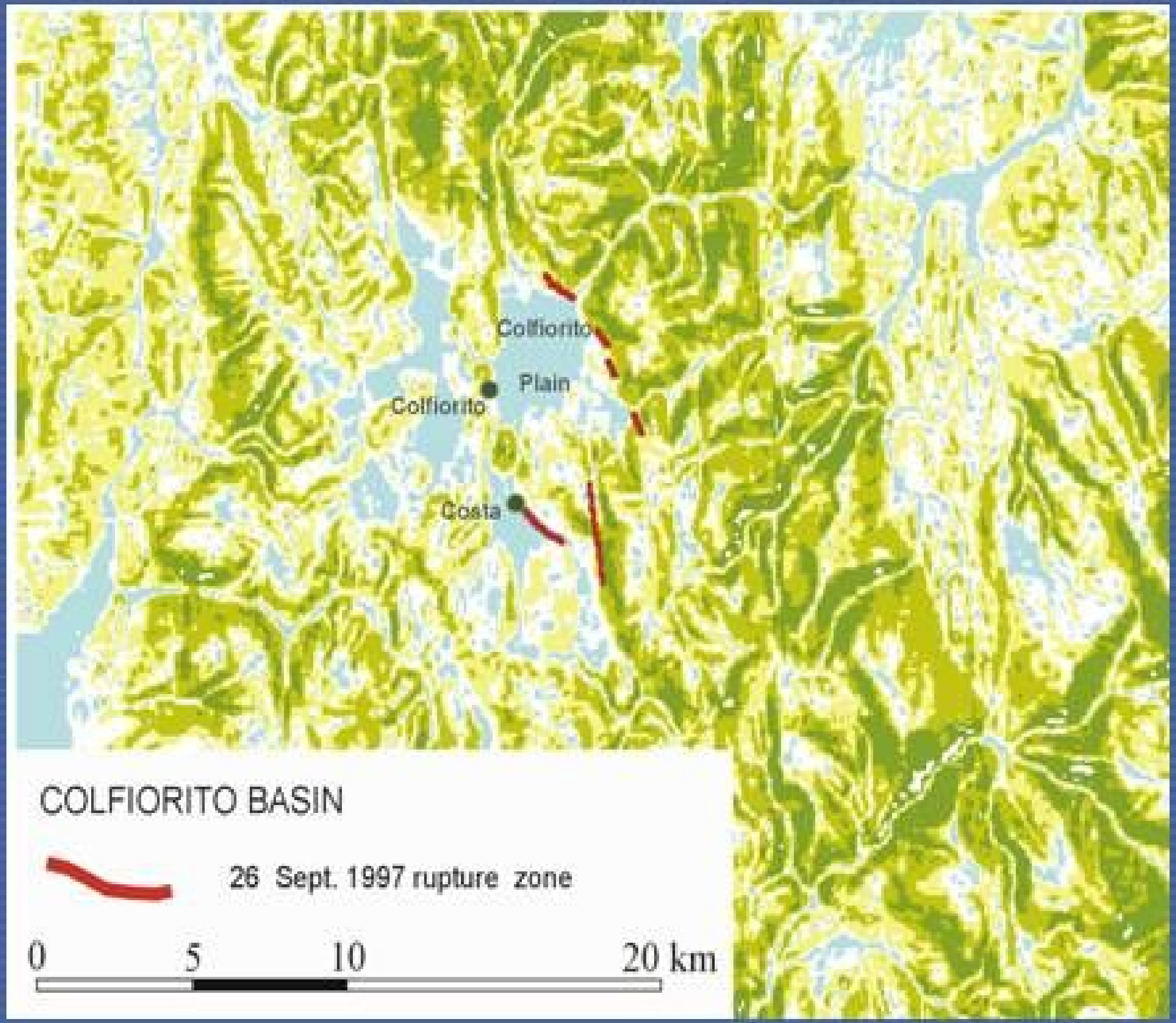
da Mayer, 1986, modificato

Potential for fault displacement at or near the site

FUCINO

COLFIORITO





RUPTURE ZONE – SIZE OF THE ASSOCIATED BASINS

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Potential for fault displacement at or near the site

INVESTIGATIONS NECESSARY TO DETERMINE CAPABILITY

Sufficient surface and subsurface related data should be obtained from the investigations in the region, near region, site vicinity and site area to show the absence of faulting at or near the site, or, if faults are present, to describe the direction, extent and history of movements on them and to estimate reliably the age of the most recent movement.

Particular attention should be paid to those geological and geomorphological features at or near the site which may be particularly useful for distinguishing faulting and which may be useful in ascertaining the age of fault movements.

When faulting is known or suspected to be present, investigations of site vicinity scale and type should be made which include very detailed geological–geomorphological mapping, topographical analyses, geophysical surveys, trenching, boreholes, age dating of sediments or fault rocks, local seismological investigations and any other appropriate techniques to ascertain when movement last occurred.

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Potential for fault displacement at or near the site

Consideration should be given to the possibility that faults that have not demonstrated recent near surface movement may be reactivated by large reservoir loading, fluid injection, fluid withdrawal or other phenomena.

Where reliable evidence shows that there may be a capable fault with the potential to affect the safety of a plant at the site, the feasibility of construction and safe operation of a plant at this site should be re-evaluated and, if necessary, an alternative site should be considered.

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Potential for fault displacement at or near the site

EARTHQUAKE EFFECTS ON THE ENVIRONMENT

Earthquakes produce effects on the environment which are also described in the intensity scales. Some of these effects (for example, surface faulting, liquefaction, coastline uplift), or their cumulative effect, can be used to recognize past earthquakes.

Potential for fault displacement at or near the site

PALEOSEISMOLOGY

The study of the geological record of past earthquakes.

Palaeoseismological studies may be useful in areas where historical earthquake records are lacking.

0 10000 20000

PALEOSEISMOLOGY

0

HISTORICAL SEISMICITY

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Potential for fault displacement at or near the site

Paleoseismological studies should be performed using the database for the following purposes:

- Identification of seismogenic structures based on the recognition of effects of past earthquakes in the region.
- Improvement of the completeness of earthquake catalogues for large events, using identification and age dating of fossil earthquakes, mainly by trenching.

- Estimation of the maximum seismic potential of a given seismogenic structure, typically on the basis of the displacement per event (trenching) as well as of the cumulative effect (seismic landscape).

- Calibration of probabilistic hazard analyses, using the recurrence intervals of large earthquakes.

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Thank you for your attention

Alessandro.Michetti@uninsubria.it