SAFE

Slow Active Faults in Europe

Assessing fundamental input for seismic risk assessment in regions of low seismicity

Project No: EVG1-2000-22005
Call Identifier: EESD-ENV-99-2-C
Thematic Priorities: 1.1.4.-7.1.

Partner 2 – Istituto Nazionale di Geofisica e Vulcanologia (Rome, Italy)

WP8 | MODELLING OF TOPOGRAPHIC SIGNAL

GIS-BASED DATABASE OF POTENTIAL EARTHQUAKE SOURCES IDENTIFIED IN SUITABLE KEY-AREAS

(Deliv 8.1)

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1. Introduction

GIS-based database of potential earthquake sources that were identified in key areas, such as the Provence, France, Po Plain, Italy, Outer Jura, Switzerland.

The seismogenic source is defined as in Valensise and Pantosti (2001) following the scheme developed in the framework of the EC project FAUST (Valensise et al., 2002).

2. GIS database software and structure

The database (figure 1) uses the commercial software MapInfo ProViewer 6.5©, or higher, that is a free software distributed by the MapInfo® Corporation through the Internet via the web site *www.mapinfo.com*. Each record of the database has a file of explanatory notes attached to it. These files were saved in the "PDF" format, thus, to visualise the content of such files the user has to have a copy of the free software AcrobatReader©, by Adobe® (available from the web site *www.adobe.com*), installed on his/her own computer.

The database has a simple, although effective, two-layer structure (figure 2). The first layer contains basic geographic information whereas the second contains data about the seismogenic sources.

The first layer is organised in four tables: (1) background topographic data; (2) outline of State boundaries; (3) geographic frame; and (4) set of labels and text.

The background topographic data is a subset of the GTOPO30 Digital Elevation Model (U.S. Geological Survey's EROS Data Center (EDC), 1996), converted into MapInfo table formats. The original data were also re-projected from their WGS84 native projection into a customized Lambert conformal conic, standard parallels 45° and 49°, central meridian 8°, that satisfies the following requirements: 1) conformity prevents vector symbols, such as the rectangle that represents the seismogenic source ideal fault plane, to be distorted, that is to say that it will always show with all sides at right angles; 2) standard parallels provide enough accuracy for distances in the area of interest.

State boundaries, map frame, labels and text are all mapped as graphic objects. The map of State boundaries has also the following attributes attached to each record: (1) name of the state; (2) name of the State's Capital; and (3) name of the continent. All fields are stored as character strings.

The second layer is organised in a single table containing data about the potential earthquake sources identified, revised, or updated within the framework of the project. It contains the graphic objects that represent the seismogenic sources prepared using the FaultStudio software (Basili, 2003). This software allows the user to manipulate the many parameters of a fault through a friendly Graphic User Interface (GUI) in a GIS environment. The software also checks the fault parameters against well-known empirical and analytical relationships between fault geometry and earthquake size (Kanamori and Anderson, 1975; Wells and Coppersmith, 1994). The GUI prompts the user with a summary of all parameters and shows the resulting fault plane in a map. An export function also facilitates the conversion between the FaultStudio internal format and the format of the records of this database. This format was adapted from that of DISS 2.0, the Italian database of seismogenic sources, and is described in detail by Valensise and Pantosti (2001).

Each record of the Database includes 29 attributes as described by the following table.

Attribute name	Variable type	Description
IDSource	Char(8)	Identification code of the seismogenic source according to the following rule: abbreviation of the Country's name, dash, ordinal number
SourceName	Char(32)	Name of a city, village or any significant locale that reminds the reader of the place where the source is located.
Strike_deg	Smallint	Orientation of the fault, in degrees, following the right-hand rule, clockwise from North.
Dip_deg	Smallint	Inclination of the fault with respect to the ground surface, in degrees.
Rake_deg	Smallint	Sense of movement of the fault, in degrees, in the range 0-360°.
Length_km	Decimal(5, 1)	Size of the fault along strike in kilometres.
Width_km	Decimal(5, 1)	Size of the fault down dip in kilometres.
MinDepth_km	Decimal(5, 1)	Vertical separation between the ground surface and the upper edge of the fault, in kilometres.
MaxDepth_km	Decimal(5, 1)	Vertical separation between the ground surface and the bottom edge of the fault, in kilometres.
LastEarthquake	Char(32)	Date of the latest earthquake caused by the fault, if known.
PrevMaxEarthquake	Char(32)	Date of the penultimate earthquake caused by the fault, if known.
RecurrenceInterval	Char(32)	Average time elapsing between two successive events of slip caused by the fault, in years.
ElapsedTime	Char(32)	Time passed since the latest earthquake caused by the fault, in years with reference to the year 2003.
SlipRate	Char(32)	Displacement versus time ratio of the fault movements, in millimetres per year.
AverageDisplacement	Char(32)	Amount of movements between the two sides of the fault during a single event of slip, in metres.
ExpectedMaxMagnitude	Char(32)	Maximum magnitude of an earthquake that can be caused by the fault, usually expressed as moment magnitude (Mw).
LonA	Decimal(8, 3)	Longitude, in decimal degrees, of one end point of the cut-off line of the fault.
LatA	Decimal(8, 3)	Latitude, in decimal degrees, of one end point of the cut-off line of the fault.
LonB	Decimal(8, 3)	Longitude, in decimal degrees, of one end point of the cut-off line of the fault.

LatB	Decimal(8, 3)	Latitude, in decimal degrees, of one end point of the cut-off line of the fault.
Lon1	Decimal(8, 3)	Longitude, in decimal degrees, of one upper corner of the rectangular surface of the fault.
Lat1	Decimal(8, 3)	Latitude, in decimal degrees, of one upper corner of the rectangular surface of the fault.
Lon2	Decimal(8, 3)	Longitude, in decimal degrees, of one upper corner of the rectangular surface of the fault.
Lat2	Decimal(8, 3)	Latitude, in decimal degrees, of one upper corner of the rectangular surface of the fault.
Lon3	Decimal(8, 3)	Longitude, in decimal degrees, of one lower corner of the rectangular surface of the fault.
Lat3	Decimal(8, 3)	Latitude, in decimal degrees, of one lower corner of the rectangular surface of the fault.
Lon4	Decimal(8, 3)	Longitude, in decimal degrees, of one lower corner of the rectangular surface of the fault.
Lat4	Decimal(8, 3)	Latitude, in decimal degrees, of one lower corner of the rectangular surface of the fault.
Notes	Char(64)	Name of the file that contains text and figures describing the seismogenic source, significant previous study about it, and main issues on its identification.

Legend: Char(n) is a n-byte-long string of text; Decimal(n,m) is a fixed-point real number of n-digit-long total length (including the decimal point) and m-digit-long decimals; Smallint is a two-byte-long integer.

The attributes attached to the records of the database can be retrieved interactively form the map the map window by using MapInfo "info" tool (figure 3). This command causes a the info window to pop up, on top of the map window, and show the full list of attributes. The last field of this list, named "Notes", contains the name of the "PDF" file that describes the seismogenic source in detail. This field is associated with the MapInfo "hot-link" tool. This tool allows the user to open with a single mouse click the linked file (figure 4), including launching the AcrobatReader software. The content of these files includes summaries of previous work done on the source, comments of the compiler of the record, open questions, digital reproduction of published figures, and an extended list of references.

The entire database is distributed as a MapInfo workspace that includes the files listed in the following table. All files are stored, for distribution purposes, in the "SAFEDB.zip" compressed archive.

File Name	Description
SAFEDB.WOR	File that contains the opening commands and visualising preferences of the database workspace.
BackgroundGTOPO30.TAB (.TIF)	Two-file suite that contains the topographic data (colour shaded relief map) shown in the map window as background raster image.
StatesOutline.TAB (.MAP; .ID; .DAT)	Four-file suite that contains the graphic objects outlining the boundaries of the European States included in the map frame.
BorderMap.TAB (.MAP; .ID; .DAT)	Four-file suite that contains the graphic objects forming the geographic frame in the map window.
BorderTXT.TAB (.MAP; .ID; .DAT)	Four-file suite that contains labels and text appearing outside the geographic frame in the map window.
SourceData.TAB (.MAP; .ID; .DAT)	Four-file suite that contains all the records of the database, i.e. the graphic objects shown in the map window and their associated attributes.
SSS-###_Name.pdf	Set of ten files in "PDF" format that contain explanatory notes on the seismogenic source. The file names are coded as follows. SSS: two- or three-character-long string that identifies the Country where the source is located; ###: three-digit-long ordinal number of the source, including leading zeros; Name: text string that identifies the name of the source.

3. The records of the database

The content of the database includes ten seismogenic sources distributed over three key-areas: Provence, France; Outer Jura, Switzerland; Po Plain and Northern Coastal Marche, Italy. The main characteristics of the identified seismogenic sources will be briefly summarised in the following list:

1) The Lambesc source (FRA-201) was identified in the key-area of Provence, France. The main issue associated with the identification of this source is that it is thought to be the source of the largest earthquake ever occurred in historical time in France, namely the Lambesc earthquake of 11 June, 1909 (Mw ~6).

2) The Basel source (CH-302) was identified in the key-area of the Outer Jura, Switzerland (although it is very close to the triple State boundary between Switzerland, France, and Germany. It is thought to be the source of the Basel earthquake of 18 October, 1356 (M ~6), that is one of the strongest earthquake occurred in the northwest and central Europe in the past 1000 years.

3) The Bagnacavallo source (ITA-100) was identified in the key-area of the Southern Po Plain, Italy. It is thought to be the source of the Romagna earthquake of 11 April, 1688 (Me 5.7). Although this earthquake is not a large one it testify the proneness of the northern Apennine piedmont to destructive earthquakes.

4) The Mantova source (ITA-103) was identified in the key-area of the Northern Po Plain, Italy. It is thought to be a silent source that has not released any earthquake in historical time. Given the controversial interpretation of the data available as of today, the main issue with this source concern its mere existence.

5) The Adige Plain source (ITA-105) was identified in the key-area of the Northern Po Plain, Italy. It is thought to be a silent source that has not released any earthquake in historical time. One important question that remains still open with this source is about its possible association with the large Verona earthquake of 1117 (Me 6.6).

6) The Mirandola source (ITA-107) was identified in the key-area of the Southern Po Plain, Italy. It is thought to be a silent source that has not released any earthquake in historical time. This source seems to have one of the faster slip rate in Italy, so one main concern with it is about how much of the slip is spent in seismic release.

7) The Orzinuovi source (ITA-104) was identified in the key-area of the Northern Po Plain, Italy. It is thought to be the source of the Valle dell'Oglio earthquake of 12 May 1802 (Me 5.6). This earthquake marks the westernmost end of historical seismicity in the southern Alps.

8) The Senigallia source (ITA-030) was identified in the key-area of the coastal Marche, Italy. It is thought to be the source of the Senigallia earthquake of 30 October 1930 (Me 5.9). This is the largest earthquake of the Adriatic coast in central-northern Italy.

9) The Fano Ardizio source (ITA-031) was identified in the key-area of the coastal Marche, Italy. It is thought to be a silent source that has not released any earthquake in historical time. This source could be a possible seismic gap in the Adriatic coastal belt framed between the Senigallia earthquake of 1930 to the South and the several earthquakes of the Riminese area, to the North, occurred in 1786, 1875, and 1916.

10) The Pesaro San Bartolo source (ITA-032) was identified in the key-area of the coastal Marche, Italy. It is thought to be a silent source that has not released any earthquake in historical time. This source could be a possible seismic gap in the Adriatic coastal belt framed between the Senigallia earthquake of 1930 to the South and the several earthquakes of the Riminese area, to the North, occurred in 1786, 1875, and 1916.

The content of the database is shown below in tabular form.

ID Source	Source Name	Strike deg	Dip deg	Rake deg	Length km	Width km	Min Depth km	Max Depth km
FRA-201	Lambesc	290	60	135	10.0	6.0	1.0	6.2
CH-302	Basel	73	45	90	17.7	9.8	1.0	7.9
ITA-100	Bagnacavallo	119	30	90	10.0	6.0	3.0	6.0
ITA-103	Mantova	262	30	90	10.0	6.0	3.0	6.0
ITA-105	Adige Plain	255	30	90	15.0	8.5	3.0	7.3
ITA-107	Mirandola	100	25	90	18.0	14.0	6.1	12.0
ITA-104	Orzinuovi	280	25	90	8.7	5.8	1.5	4.0
ITA-030	Senigallia	132	30	90	12.0	6.0	3.0	6.0
ITA-031	Fano Ardizio	132	30	90	12.0	8.0	3.0	7.0
ITA-032	Pesaro San Bartolo	122	30	90	8.0	6.0	3.0	6.0

Last Earthquake	Previous Max Earthquake	Recurrence Interval	Elapsed Time	Slip Rate
11 Jun 1909	Unknown	500-6000 y*	94	Unknown (0.1-1.0 mm/y*)
18 Oct 1356	Unknown	1000-10000 y*	647	Unknown (0.1-1.0 mm/y*)
11 Apr 1688	Unknown	700-3000 y*	315	Unknown (0.1-1.0 mm/y*)
Unknown	Unknown	700-5000 y*	Unknown	Unknown (0.1-1.0 mm/y*)
Unknown	Unknown	700-6000 y*	Unknown	Unknown (0.1-1.0 mm/y*)
Unknown	Unknown	700-5000 y*	Unknown	Unknown (0.1-1.0 mm/y*)
12 May 1802	Unknown	700-3000 y*	201	Unknown (0.1-1.0 mm/y*)
30 Oct 1930	Unknown	700-4000 y*	70	Unknown (0.1-1.0 mm/y*)
Unknown	Unknown	700-6000 y*	Unknown	Unknown (0.1-1.0 mm/y*)
Unknown	Unknown	700-4000 y*	Unknown	Unknown (0.1-1.0 mm/y*)

Average Displacement	Expected Max Magnitude	LonA	LatA	LonB	LatB	Lon1

0.55 m*	5.8 (Me); 5.8<Mw>6.1	5.183	43.660	5.300	43.629	5.185
1.0 m*	6.2 (Mw)	7.750	47.527	7.525	47.480	7.754
0.3 m*	5.7 (Me); 5.8 (Mw)	11.959	44.461	12.069	44.417	11.927
0.5 m*	5.9 (Mw)	10.808	45.085	10.682	45.073	10.799
0.6 m*	6.2 (Mw)	11.279	45.263	11.094	45.228	11.262
0.5 m*	6.3 (Mw)	11.003	45.027	11.229	44.999	10.974
0.3 m*	5.7 (Mw); 5.6 (Me)	9.783	45.442	9.893	45.428	9.790
0.4 m*	5.9 (Me)	13.165	43.787	13.276	43.715	13.122
0.6 m*	6.1 (Mw)	12.940	43.917	13.051	43.845	12.897
0.4 m*	5.8 (Mw)	12.829	43.998	12.914	43.960	12.795

Lat1	**Lon2**	**Lat2**	**Lon3**	**Lat3**	**Lon4**	**Lat4**	**Notes**
43.665	5.302	43.634	5.315	43.659	5.198	43.690	FRA-201_Lambesc. pdf
47.518	7.529	47.471	7.556	47.412	7.781	47.458	CH-302_Basel.pdf
44.420	12.038	44.377	12.006	44.336	11.896	44.379	ITA-100_Bagnacavallo. pdf
45.131	10.673	45.119	10.663	45.165	10.790	45.178	ITA-103_Mantova. pdf
45.308	11.077	45.273	11.052	45.337	11.237	45.372	ITA-105_AdigePlain. pdf
44.911	11.200	44.883	11.172	44.771	10.946	44.799	ITA-107_Mirandola. pdf
45.470	9.900	45.457	9.912	45.503	9.802	45.517	ITA-104_Orzinuovi. pdf
43.752	13.233	43.680	13.190	43.645	13.078	43.718	ITA-030_Senigallia. pdf
43.882	13.008	43.810	12.950	43.764	12.839	43.836	ITA-031_FanoArdizio. pdf
43.958	12.879	43.920	12.845	43.881	12.760	43.919	ITA-032_PesaroSanBartolo.pdf

The data in the above table can be used also to re-create the database within any other GIS software environment or hardware platform. The fields named Lon# and Lat# can be used to draw the graphical objects that represent the seismogenic sources in any GIS or mapping tool. Any entire record can also be used for modelling purposes such as coseismic/interseismic displacement, stress/strain change, or peak ground acceleration. Notice that " * " indicates that the so marked value was estimated using general considerations or the compiler judgment. Some slip rates were assumed on the basis of geodynamic constraints whereas recurrence intervals could have been inferred from slip rate and average displacement and so on. However, the user is cautioned in using these data for seismic hazard estimates or urban/facility planning that go beyond demonstration purposes. In fact, the database was not devised for such usage and its content totally lacks completeness, which is a very crucial factor in seismic hazard assessment and related estimates.

4. References

Basili R., 2003. New software for the analysis of landscape response to faulting. Deliverable 8.3, WP8: modelling of topographic signal, EU Project SAFE, EVG1-2000-22005.

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Wells, D.L., and Coppersmith, K.J., 1994. New Empirical Relationships among Magnitude, Rupture Lenght, Rupture Width, Rupture Area, and Surface Displacement, Bull. Seism. Soc. Am., 84, 974-1002.

Figure captions

Figure 1. The MapInfo ProViewer program window with the database open in a map child-window and the "About" dialog displaying on the right-hand side.

Figure 2. The two layer structure of the database open in a map child-window and the "About" dialog displaying on the right-hand side.

Figure 3. A sample record of the database. The attributes of the ITA-032, Pesaro San Bartolo, seismogenic source, are displayed in a child-window as they are retrieved by using the MapInfo "Info" tool.

Figure 4. A sample record of the database. The file that contains the explanatory notes linked to the ITA-032, Pesaro San Bartolo, seismogenic source, is shown open in the AcrobatReader program window. The file appears as it is retrieved by using the MapInfo "Hot Link" tool.

Figure 1

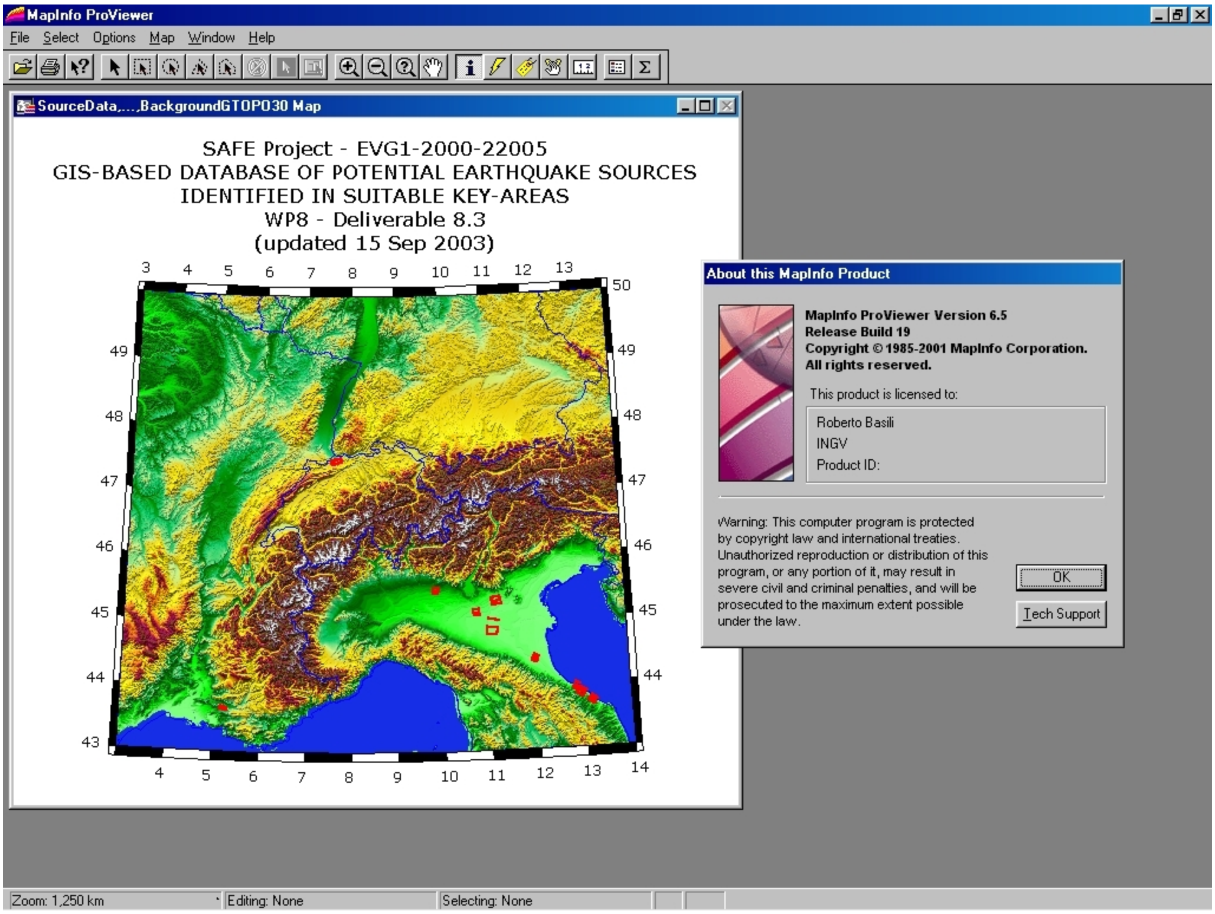

MapInfo ProViewer
File Select Options Map Window Help
SourceData,...,BackgroundGTOPO30 Map
SAFE Project - EVG1-2000-22005
GIS-BASED DATABASE OF POTENTIAL EARTHQUAKE SOURCES
IDENTIFIED IN SUITABLE KEY-AREAS
WP8 - Deliverable 8.3
(updated 15 Sep 2003)
About this MapInfo Product
MapInfo ProViewer Version 6.5
Release Build 19
Copyright © 1985-2001 MapInfo Corporation.
All rights reserved.
This product is licensed to:
Roberto Basili
INGV
Product ID:
Warning: This computer program is protected by copyright law and international treaties. Unauthorized reproduction or distribution of this program, or any portion of it, may result in severe civil and criminal penalties, and will be prosecuted to the maximum extent possible under the law.
OK
Tech Support
Zoom: 1,250 km
Editing: None
Selecting: None

Figure 2

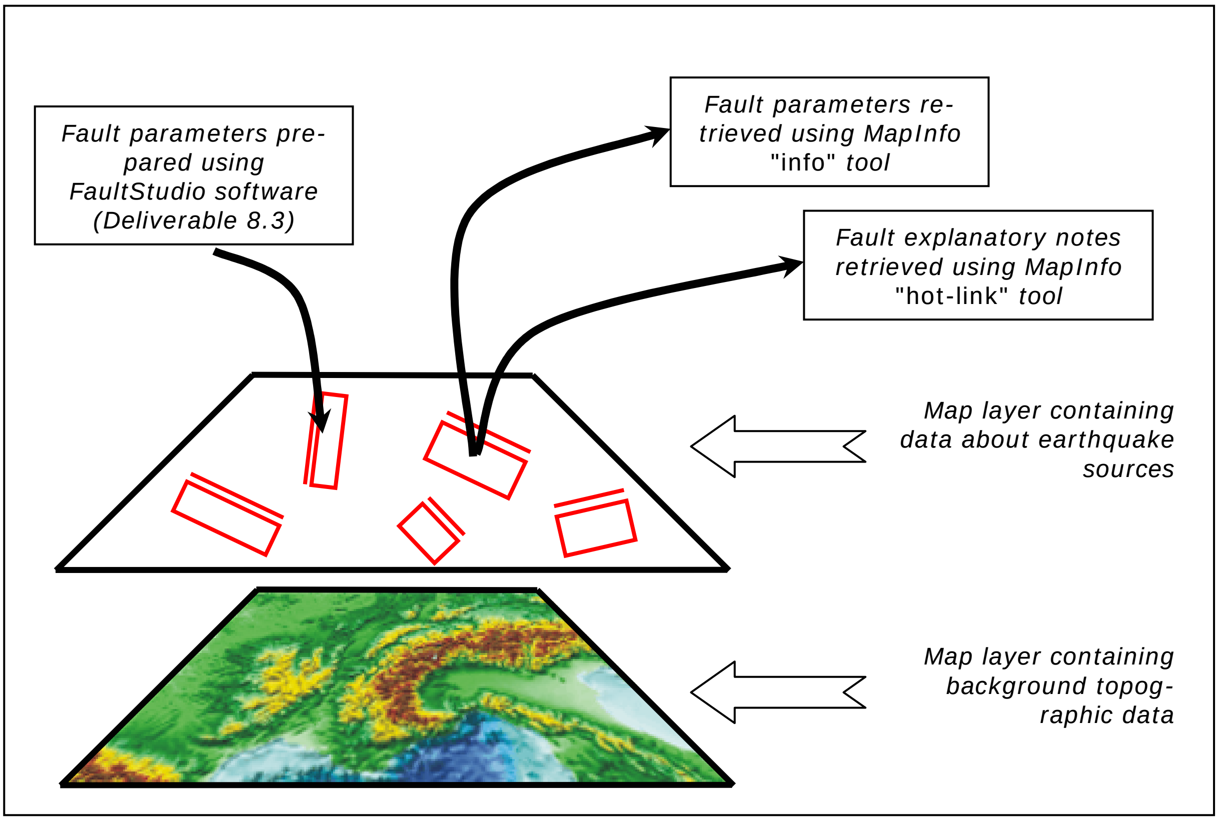

Fault parameters pre-pared using FaultStudio software (Deliverable 8.3)
Fault parameters re-trieved using MapInfo "info" tool
Fault explanatory notes retrieved using MapInfo "hot-link" tool
Map layer containing data about earthquake sources
Map layer containing background topog-raphic data

Figure 3

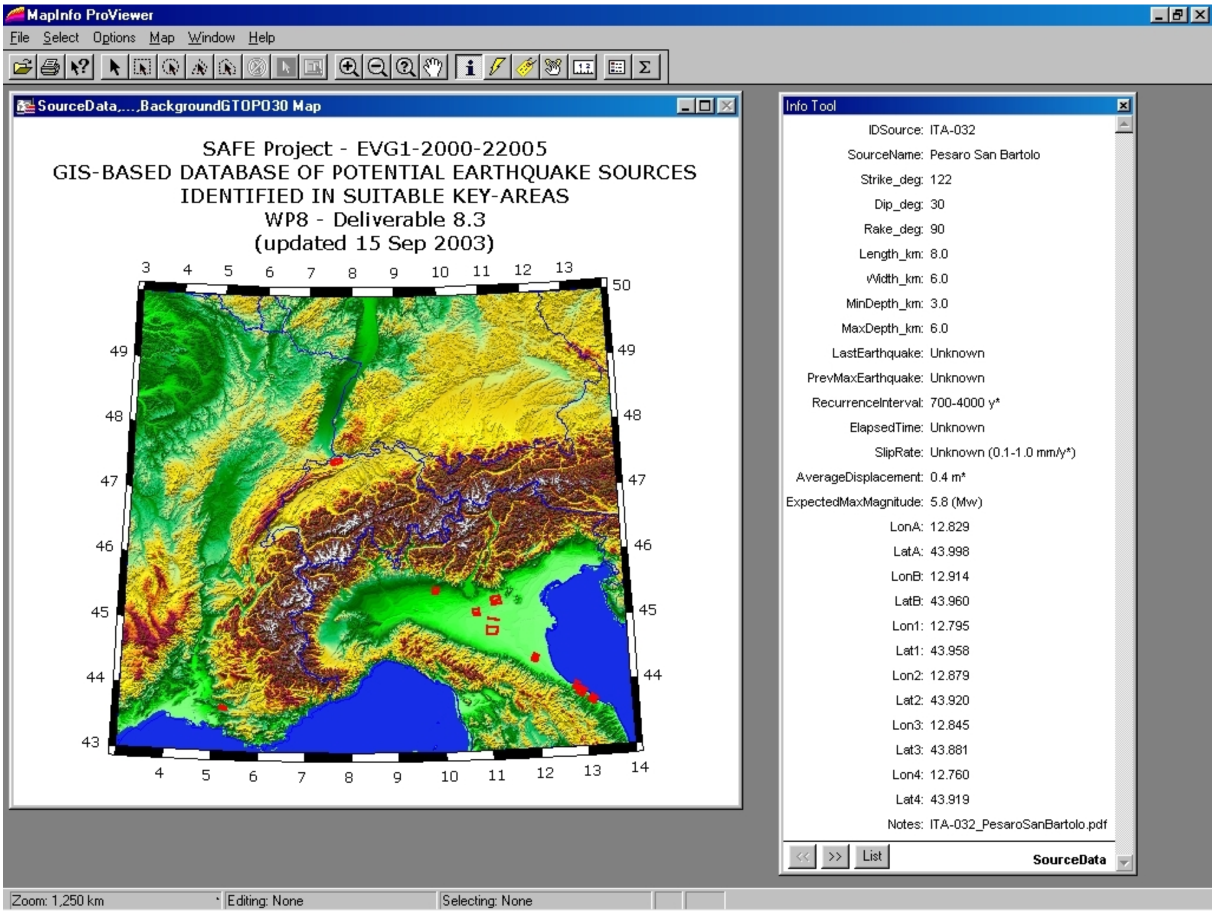
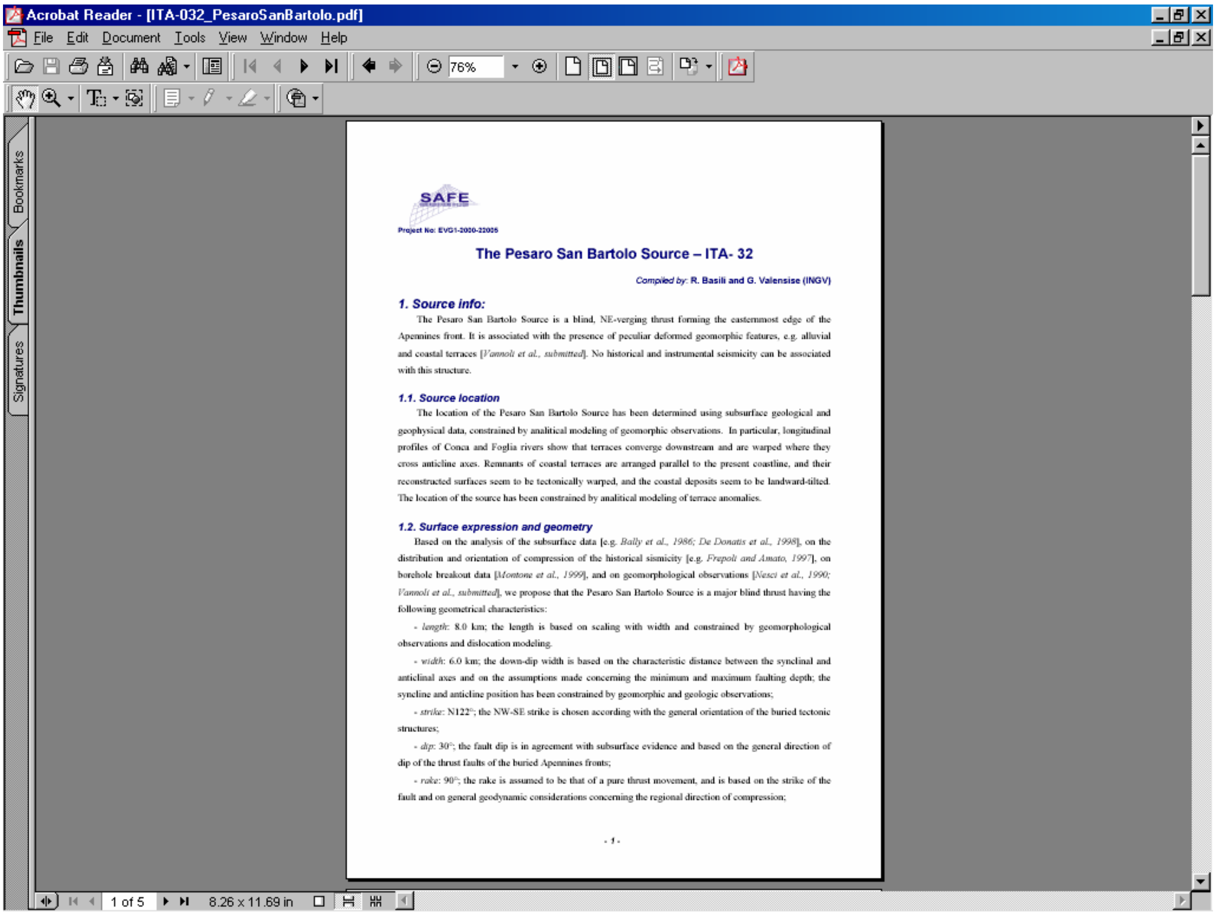

MapInfo ProViewer
File Select Options Map Window Help
SourceData,...,BackgroundGTOPO30 Map
SAFE Project - EVG1-2000-22005
GIS-BASED DATABASE OF POTENTIAL EARTHQUAKE SOURCES
IDENTIFIED IN SUITABLE KEY-AREAS
WP8 - Deliverable 8.3
(updated 15 Sep 2003)
Info Tool
IDSource: ITA-032
SourceName: Pesaro San Bartolo
Strike_deg: 122
Dip_deg: 30
Rake_deg: 90
Length_km: 8.0
Width_km: 6.0
MinDepth_km: 3.0
MaxDepth_km: 6.0
LastEarthquake: Unknown
PrevMaxEarthquake: Unknown
RecurrenceInterval: 700-4000 y*
ElapsedTime: Unknown
SlipRate: Unknown (0.1-1.0 mm/y*)
AverageDisplacement: 0.4 m*
ExpectedMaxMagnitude: 5.8 (Mw)
LonA: 12.829
LatA: 43.998
LonB: 12.914
LatB: 43.960
Lon1: 12.795
Lat1: 43.958
Lon2: 12.879
Lat2: 43.920
Lon3: 12.845
Lat3: 43.881
Lon4: 12.760
Lat4: 43.919
Notes: ITA-032_PesaroSanBartolo.pdf
List
SourceData
Zoom: 1,250 km
Editing: None
Selecting: None

Figure 4



Project No: EVG1-2000-22005

The Pesaro San Bartolo Source – ITA- 32

Compiled by: R. Basili and G. Valensise (INGV)

1. Source info:

The Pesaro San Bartolo Source is a blind, NE-verging thrust forming the easternmost edge of the Apennines front. It is associated with the presence of peculiar deformed geomorphic features, e.g. alluvial and coastal terraces [*Vannoli et al., submitted*]. No historical and instrumental seismicity can be associated with this structure.

1.1. Source location

The location of the Pesaro San Bartolo Source has been determined using subsurface geological and geophysical data, constrained by analitical modeling of geomorphic observations. In particular, longitudinal profiles of Conca and Foglia rivers show that terraces converge downstream and are warped where they cross anticline axes. Remnants of coastal terraces are arranged parallel to the present coastline, and their reconstructed surfaces seem to be tectonically warped, and the coastal deposits seem to be landward-tilted. The location of the source has been constrained by analitical modeling of terrace anomalies.

1.2. Surface expression and geometry

Based on the analysis of the subsurface data [e.g. *Bally et al., 1986; De Donatis et al., 1998*], on the distribution and orientation of compression of the historical sismicity [e.g. *Frepoli and Amato, 1997*], on borehole breakout data [*Montone et al., 1999*], and on geomorphological observations [*Nesci et al., 1990; Vannoli et al., submitted*], we propose that the Pesaro San Bartolo Source is a major blind thrust having the following geometrical characteristics:

- *length*: 8.0 km; the length is based on scaling with width and constrained by geomorphological observations and dislocation modeling.
- *width*: 6.0 km; the down-dip width is based on the characteristic distance between the synclinal and anticlinal axes and on the assumptions made concerning the minimum and maximum faulting depth; the syncline and anticline position has been constrained by geomorphic and geologic observations;
- *strike*: N122°; the NW-SE strike is chosen according with the general orientation of the buried tectonic structures;
- *dip*: 30°; the fault dip is in agreement with subsurface evidence and based on the general direction of dip of the thrust faults of the buried Apennines fronts;
- *rake*: 90°; the rake is assumed to be that of a pure thrust movement, and is based on the strike of the fault and on general geodynamic considerations concerning the regional direction of compression;

- 1 -