

Probable earthquakes in Italy between 2000 and 2030: guidelines for determining priorities in seismic risk mitigation

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Introduction

This report summarizes the activities of the project in the three Working Groups (Gruppi di lavoro, GdL) in which the project is organized. For more details on methodologies and results the reader is referred to the attached reports. The objectives of the three GdL for the second year are listed below:

GdL 1

- Improvement of research on selected sources in least known seismic areas (task 1.1)
- Introduction of newly identified sources in the database (task 1.1)
- Analysis of the role and contribution of new information layers (task 1.1)
- Contribution to the implementation of a new scheme for seismic hazard (task 1.1)
- Extensive historical investigation in the "seismic gap" areas (task 1.2)
- Re-evaluation of crucial data points (task 1.2)
- Intensity assessment from new and revised information (task 1.2)
- Geodetic deformation estimate in Sicily and southern Apennines (task 1.3)
- Seismic deformation estimate (task 1.3)
- Vertical deformation from levelling lines and geological data (task 1.3)
- Selection of new potential seismic gaps (task 1.4)
- Analysis of seismological data in the selected areas (task 1.4)
- Differential interferograms and coherence maps (task 1.4)

GdL 2

- Integrated instrumental catalogue 1981-2000 (task 2.1)
- Md-MI empirical relations (task 2.1)
- 3D regional velocity models (task 2.1)
- Integrated database of P-wave arrival times from seismic refraction lines 1968-2002 (task 2.2)
- 2-D Vp models and first 3D regional models (task 2.2)

GdL 3

- Empirical scaling relationships in Sicily and northern Italy (task 3.1)
- Anelastic attenuation modeling in terms of crustal attenuation $Q(f)$ and k (task 3.1)
- Duration of the ground shaking, peak ground acceleration/velocity (task 3.1)
- Collection and informatization of forms on geological features of the Italian Municipality districts (task 3.2)
- Estimate of the effects of surface geology on hazard at a national scale (task 3.2)
- Detailed reconstruction of local geology in gap areas and estimate of effects on hazard parameters through numerical modelling (task 3.2)
- Analysis of relationships between earthquakes and generated tsunamis (task 3.2)
- Tsunamigenic zonation of Italian seas (task 3.2)
- Collection and preanalysis of bathymetric data with particular regard to the coastal area (task 3.2)
- Gathering and pre-analysis of geo-morphological data of Italian coasts (task 3.2);
- Building of preliminary grids of finite elements suitable for codes of numerical simulation (task 3.2)

Simulation of sample cases and pre-analysis of maximum wave (task 3.2)

Detailed analyses in test areas (task 3.4)

Validation of the proposed model using observed data (task 3.4)

Formulation of an integrated model (task 3.4)

GdL 1: The seismogenic model of Italy

The objectives of GdL 1 for the second year of the project were the estimate of geodetic deformation in peninsular Italy, its comparison with seismic deformation, the analysis of new seismogenic sources and further studies on some previously known faults with new geomorphology and historical data. In addition, the identification and characterization of some potential “seismic gaps” has been continued. The seismogenic model of Italy will be built on the integration of the basic data described. Moreover, an original seismogenic model of Italy has been sketched, starting from the critical analysis of previous seismotectonic model, using DISS (the database of potential seismic sources, see next paragraph) and data on historical and recent seismicity. This will be used for conventional estimates of seismic hazard.

Improvement of the Database of Italian Seismic Sources “DISS” (task 1.1-1.2)

The catalogue DISS, released in December 2001, is the first strategic objective of Task 1.1. It was released on CD and published on a special volume of *Annali di Geofisica*, where the contents and the access procedures are explained (Vol. 44, 4, 2001, G. Valensise and D. Pantosti, eds.).

DISS includes sixty seismogenic sources constrained by geological, historical and geophysical data. Fourteen of them do not have an associated earthquake and are therefore proposed as “potential seismic gaps”. Their characterization is one of the main objectives of the project.

During 2002 both task 1.1 and 1.2 have worked on the identification of new sources and on the improvement on previously known seismogenic faults. The main results are summarized below:

New seismogenic sources from geology, geomorphology and historical data

Alta Val Tiberina. Two new seismic sources relative to the 1917 (Monterchi-Citerna, Me 5.9) and 1789 (Val Tiberina, Me 5.6) were added.

Valle Umbra. Three seismogenic sources responsible for the earthquakes of Foligno (1832, Ma 5.1), Bastia (1854, Me 5.6) and Montefalco (1878, Me 5.3) have been included.

Molise earthquakes. Two new seismogenic faults associated to the earthquakes of October 31 (Mw 5.4) and November 1 (Mw 5.3), 2002, were added to DISS.

Review of previously identified seismogenic sources

Orzinuovi fault. A review of historical data for the Socino earthquake of 1802 (Me 5.9), and the study of the relationship between subsurface geology and geomorphology provided new constraints to improve the fault reported in DISS 2.0 (Albini et al., 2002).

Mirandola fault (seismic gap?). Ciucci et al. (2002) have studied the drainage anomalies of rivers Secchia and Panaro. The integration between subsurface data and geomorphological features allowed us to constrain the location and geometry of this fault and to estimate a slip rate of about 1.7 mm/y. Burrato et al. (2003) discuss this fault in the framework of the seismogenesis in the Po Plain.

Marche coastal region. (seismic gaps?). Vannoli et al. (2003) performed a geomorphological study to identify and characterize the tectonic structures along the Adriatic coast between Rimini and Ancona. The analysis of river drainage and of deformed fluvial and coastal terraces allowed us to define the geometry and segmentation of faults, confirming the presence of two potential "seismic gaps". Vannoli et al. (2002) estimate an average slip rate of 0.2-0.4 mm/y for these faults.

Gubbio basin (seismic gap?). Pucci et al. (2003) provided new results to constrain the active faults of this area, through field investigations, aerial photos and DEM studies. The integration with recent seismological data shows how the low angle normal fault constituting the Gubbio fault is made of two distinct segments capable to produce M 5.3-5.9 earthquakes. The southern segment was likely activated during the 1984 shock, whereas the northern segment is a potential "seismic gap".

Historical research on areas of potential seismic gap (Alta Val Tiberina)

Although preliminary, the results to date (Castelli, 2002) supply interesting evidence for a few, unknown damaging earthquakes, the location and size of which still needs careful analysis and, possibly, further data. One of the main findings is a destructive event in 1558, the evidence of which emerged in the recent years and is now confirmed as badly damaging at Città di Castello. Traces of a few, badly damaging events have also been found in both the upper Tiber and Arno valleys in the XIII, XV, XVI and XVII centuries: they are presently being analyzed for addressing further investigation.

Seismic and geodetic deformation (task 1.3)

E' stata conclusa l'analisi dei dati GPS acquisiti nel 2001 e nel 2002 sui monumenti IGM in Italia peninsulare e determinati i tassi di *shear strain* in un intervallo di 126 anni (Hunstad et al., 2003). I risultati mostrano che:

- il processo dominante in Appennino è estensione in direzione NE-SW;
- il segnale geodetico lungo la fascia tirrenica e adriatica è paragonabile con l'errore associato alle misure, fatta eccezione per il Gargano;
- gli *shear strain* in Appennino sono dell'ordine di $0.5-1 \cdot 10^{-7} \text{ yr}^{-1}$. Tale *strain*, se integrato attraverso la fascia appenninica, fornisce stime del tasso di estensione dell'ordine di 2.5-5.0 mm/yr con incertezze di circa 1-1.5 mm/yr;
- I valori di *shear strain* geodetici sono stati confrontati con gli *strain* sismici osservati nello stesso intervallo temporale delle stime geodetiche. Il confronto mostra che esiste una ottima corrispondenza nelle direzioni degli assi principali dei tensori di *strain* geodetico e sismico. Il valore però differisce sensibilmente suggerendo che in Appennino si è accumulato uno *strain* elastico importante. Estendendo il confronto su una scala temporale maggiore (700 anni di deformazione sismica) si osserva che, in Appennino, a lungo termine solo il 25% della deformazione geodetica è rilasciata da terremoti.

In ultimo, nell'autunno 2002 sono stati misurati i 14 vertici IGM in Sicilia. I risultati mostrano un consistente pattern delle deformazioni geodetiche negli Iblei con tassi di deformazione dell'ordine di $1-2 \cdot 10^{-7} \text{ yr}^{-1}$.

E' stato concluso il lavoro sulle linee di livellazione, che fornisce un limite superiore dei movimenti verticali attraverso l'Italia.

In generale, i risultati forniscono principalmente un vincolo tettonico e si integrano con il catalogo DISS per una visione comprensiva della deformazione attiva in Italia.

Studies on the potential seismic gap areas (Città di Castello, Val d'Agri, Melandro-Pergola) (task 1.4)

In the test areas considered as “potential seismic gaps” (Alta Val Tiberina, Campania-Lucania Apennines) we performed specific detailed analyses, such as:

- Subsurface studies of extensional basins through geoelectric surveys and stratigraphic analyses of drilled wells;
- Seismotectonic and kinematic analyses through the review of historical and recent seismicity, focal mechanisms, and seismic reflection lines;
- Elastic strain accumulation through InSAR images.

The historical seismicity is located in correspondence of areas of no or weak instrumental seismicity. This is concentrated in the eastern sector of the Alta Val Tiberina basin. Some recent seismic swarms near Sansepolcro are located in the NE edge of the basin. Presently our hypotheses are:

1. In analogy with the southern sector, we propose a normal fault trending N130-160 dipping 40°-60° to the west. This fault has a length of 10-15 km, does not reach the surface and can generate earthquakes with a maximum magnitude ~6.
2. The studies on the “Faglia Alto-Tiberina” suggest a fault on its western margin, with a slightly variable trend, a dip of ~20° and a length of ~15 km, capable of generating minor seismicity.

In the Val d'Agri basin (Basilicata) the main fault is the one located on the eastern side of the valley, dipping to the southwest, but the analysis of recent seismicity also suggest the activity of NE-dipping faults, located in the western side of the basin.

To the north, the Melandro-Pergola fault is likely trending NW-SE, has an extensional kinematics and is located at the surface on the western side of the basin.

Differential interferograms (14 for the Alta Val Tiberina, 5 in southern Apennines) between 1992 and 2002 have been obtained to have a stack that could minimize the atmospheric contribution. A DEM with a resolution of 20 m has been computed in order to reduce the effect of the topography on InSAR images. The results show some residual differential fringes that can be interpreted in terms of crustal deformation, and will be analyzed in the third year of the project. Through a GIS, the SAR results have been compared to seismological and tectonic data.

We have decided not to start new studies in other areas of potential gap, but rather to increase the research in the two selected areas, extending to adjacent regions, because many new data have been collected in these regions that need to be fully exploited.

General elements for a new conventional seismic zonation (task 1.2)

As a side product of this GdL, a research was undertaken to supply an updated seismogenic zonation: a) consistent with the state-of-the-art of the active tectonics in Italy and mostly with DISS, b) in which the size of the zones is such that the number of earthquakes in each zone is a reliable sample for statistical evaluations. As a first step the former ZS4, still popular with the users, was remastered into a new zonation

ZS6, obtained reducing the number of ZS from 80 to 25, mainly by joining together contiguous ZS with similar background, without modifying the original geometry. In addition: i) the CPTI catalogue (which should not be used together with ZS4 as the two items have different backgrounds) is now consistent with the new zonation; ii) for each new seismic zone a set of completeness time-intervals based on historical evidence was provided. As a second step, a prototype version of ZS9, where seismic zones are designed adopting new criteria (expected M_{max} when possible, for instance) was designed for north-western Italy, and a first attempt for the whole Italian region was also sketched (Stucchi et al., 2002).

GdL 2: Recent seismicity and velocity models

The objective of GdL 2 for the second year was the compilation of a catalogue of seismicity until 2000 and the definition of crustal three-dimensional velocity models, including resolution analyses. Another important objective is the implementation of a database of arrival times from the DSS (seismic refraction profiles) shot in Italy from 1968 to present, and their integration in the 3-D velocity models.

Instrumental catalogue 1981-2002 and related velocity models (tasks 2.1-2.3)

A new instrumental catalogue from 1981 to 2002 has been collected in the framework of the GNDT project. The catalogue contains the largest number of locations, duration magnitudes and P and S arrival times of Italian earthquakes occurred during 1981-2002. More than 73,000 events have been located making use of more than 700,000 and 600,000 P and S waves, respectively, recorded by both INGV national network and by regional and local networks.

Locations were computed using Hypoellipse. Besides the hypocentral location, for each event the catalogue contains error estimate, root mean square residuals, azimuthal gap, and number of phases per location.

In particular, the previous GNDT catalogue 1981-1996 has been used for the period 1981-1996. This catalogue contains 39,723 located events recorded at a total of 467 stations. We determined new event associations for the period 1997-2002 (including the very large dataset from Umbria-Marche earthquake sequence). New associations have been checked before and after event location verifying that the P and S residuals were below a predetermined threshold.

The final dataset 1997-2002 includes 32,644 events recorded at 411 stations. Ad hoc procedure are under study to diffuse all the information contained in the catalogue.

3D velocity models have been computed for the upper mantle and the crust from the P arrival times contained into the integrated catalogue. The inversion has been performed using 24,246 selected arrival times at 717 seismic stations allowing us to get a high resolution of the tomographic images. The variance reduction is about 50% and the final rms is lower than 0.5 s.

The resolution of the velocity model is 15 km in x and y in the 2 crustal layers (8.22 km), and in the 4 mantle layers (38, 52, 66, 80 km). The final model allows us to gain a better definition with respect to previously available images. The velocity model brings new evidence to interpret the Italian active tectonics. 3D locations are the next step of the task, together with the integration of data from DSS data (task 2.2).

Besides the new integrated catalogue, original waveforms of the Italian national network were made available for the period 1988-2002. The waveforms database

has been carried out in the framework of the project and is available at <http://waves.ingv.it>. Besides the waveforms, it is possible to download all the main event parameters and phase readings.

The MI-Md relations will be calibrated after an homogeneous estimate of signal duration will be calculated from the waveforms database (in progress).

2-D and 3-D crustal velocity model of Italy from active seismology (task 2.2)

During the second year of activity carried out by the research unit 2 of Milan CNR in the frame of the project, it was concluded the picking of the P-wave first arrivals detected on the refraction seismic sections which have been recorded from 1968 till now in the Italian territory, and the construction of the database containing such arrivals together with other information about each profile.

In particular the first-arrivals picking has been performed on 419 seismic sections recorded along the lines relative to the following projects: Sicilia 72, Etna 77, Sicilia 80, Sicilia 84, Puglia 72, Calabria 70, Calabria 72, Calabria 79, Tirreno 71, Appennini 74, Toscana 78, Bolsena, DSS79-80, Crop03, Umbria 81-84, Btp 91, Sardegna 82, Ecors 85, Ecors 87, Alp 75, Friuli 78, Sudalp 77, Appennini 83-85, EGT 83, EGT 86, Appennini 87, Bardi 87, Lisa, Cropmare 94, Tomoves 94 and Tomoves 96. Of 419 sections analysed 40 were recorded as fan.

Some of the data contained in the data set are high-density wide-angle reflection/refraction data (WARR), like the data relative to Lisa and Cropmare experiment. These have been acquired in 1994 jointly with near-vertical seismic data (NVR) by three-components seismic stations located along the Italian coast. The seismic sections relative to the other projects had been recorded by analogical devices, digitised and controlled by the former IRRS Institute of Milan CNR (Biella et al., 1994; Osculati et al., 1995; Ferrari et al., 1998) and recently processed by IDPA Institute (Corsi 1999a; Corsi 1999b).

The P-phase first arrivals picking has been carried out manually by an algorithm which has been implemented in Matlab environment.

The procedure adopted for first-arrivals recognition is based on the analysis of the Hilbert transform of the signals, which represents the envelope of the wave connected to the seismic phase, of the characteristic function CF defined by Allen (1978) as $CF = s_i^2 + (s_i - s_{i-1})^2$, where s_i is the seismogram and of the signal itself.

The onset time in each seismic trace is picked independently on the three functions and the first-arrival time is calculated as their mean value.

In order to avoid over- or under-fitting of the data and to allow the appropriate weighting of the contribution to the solution from relatively certain and uncertain picks when the inverse modelling will be carried out, an uncertainties value was assigned to each first-arrival time picked. The picking algorithm used performs the error estimate by evaluating the noise level in the portions of the Hilbert transform of the traces preceding the first-arrival time; the uncertainty is given by the time interval between the onset and the first subsequent sample where the Hilbert transform exceeds the estimated noise level.

On the DSS and wide-angle seismic sections analysed 11820 P-wave first arrivals have been identified and input to the database together with their uncertainties, the 1D velocity-depth functions and other important characteristics of each profile. The database has been constructed by Microsoft Access.

The arrival times which have been recognised are Pg and Pn phases relative to diving waves respectively in the upper crust and in the upper mantle and the mean error is 0.025 s.

For each of the travel time-offset curve input to database a 1-D velocity model has been calculated. Actually, the velocity-depth functions have been estimated according three different modellings: a model assuming a constant velocity-gradient, a varying velocity-gradient model and a layered model.

In order to carry out regional or local tomographic analyses, average 1D velocity models relative to particular areas have been determined. In these cases only constant gradient and variable gradient models have been calculated, which could be used as starting model for the tomographic inversion. These have been obtained both inverting the average travel time-offset function relative to the particular area and by calculating the mean velocity-depth function over those relative to each profile of the same area.

GdL 3: Regional attenuation laws, effects of local geology, and hazard models

The work of GdL has been the determination of regional attenuation laws, the estimate of local geology on ground shaking at national scale, the evaluation of time-dependent seismic hazard maps, and the definition of tsunami hazard in Italy.

Regional ground motion scaling (task 3.1)

Goal of this Task is the determination of the regional ground motion scaling in areas of Italy that have to be assumed homogeneous (on average) from the point of view of wave propagation.

Since wave propagation does not change with magnitude (except when nonlinear behaviors arise close to the surface, generally on unconsolidated sediments when these shallow materials experience strong ground motion) and since strong ground motion is seldom recorded, we exploit large amounts of recordings from the background seismicity in order to quantify the average attenuation properties of the crust in relatively homogeneous regions. Regressions are performed on very large data sets of ground motion waveforms, both on peak values of narrowband-filtered versions of the time histories, and on Fourier amplitudes (see Malagnini et al, 2000, 2002 for details). Along with source, attenuation, and site terms, the regressions are done also on a functional form that quantifies the duration of the signal as a function of frequency and hypocentral distance. The mathematical tool of Random Vibration Theory is extensively used to model/predict peak values as a function of distance and frequency, or even as absolute values (e.g. PGA, PGV).

The regions investigated in 2002 were the Eastern and Western Alps (Malagnini et al., 2002a,b, Morasca et al., 2002, using about 18,000 waveforms from 1800 events and ~6,000 waveforms from 962 earthquakes, respectively), Eastern Sicily (117 events, 1420 time histories, Scognamiglio et al., 2002), and the Central Apennines (about 521 events, 8079 waveforms, from a data set of 2000 earthquakes, ~60,000 waveforms, available. Resources for studying the latter region were drawn from Task 3.1 of the GNDT project coordinated by Massimo Cocco).

For the other region that we intended to study, Garfagnana, we have selected 605 events, for a total of about 3000 seismograms. Although the preprocessing has already been performed, no final results are available yet for Garfagnana.

Effects of surface geology on hazard parameters (task 3.2)

Goals of the 2nd year activity for this task are:

- 1) Collection and informatization of forms on geological features of the Italian Municipality districts;
- 2) Estimate of the effects of surface geology on hazard at a national scale;
- 3) Detailed reconstruction of local geology in gap areas and estimate of effects on hazard parameters through numerical modelling.

1) About 23% of forms sent to the technical office of all the Municipality districts of Italy have been filled and sent back to INGV, both via Internet and by mail. A procedure is operating on a web page for data archiving online. Forms sent by mail will be stored on the same database.

2) The geological map of the Italian territory (scale 1:500.000) edited by SSN has been simplified to three classes of the EC8 classification (type A, B, and C, corresponding to rock, stiff and soft, respectively). The result of this zoning is shown in Figure 2a, where a grid of 250 m is used. A procedure has been implemented that computes the EC8 elastic response spectra (pseudo-acceleration) in each grid cell as a function of surface geology. Starting from a PGA hazard map for the rock category, it is thus possible to compute hazard maps where the effect of surface geology are taken into account according to the EC8 criteria (ENV 98). Geology-corrected maps are computed for PGA, Housner spectral intensity, and pseudovelocity response spectra at 0.3, 1 and 2 sec. For a critical evaluation of the precision of a 1:500000 scale, a test based on the *Confusion Matrix Method* has been performed which indicates that errors are of the order of 20% to 40% for the different soil categories compared with more detailed geological maps (1:10000 e 1:5000). Moreover, one most important test is in progress to check the real incidence of large-scale surface geology on the damage distribution. The intensity maps of Friuli, Irpinia, Umbria-Marche, Lazio-Abruzzo earthquakes consist of several thousands of data and are adequate for this check. The result of this test will be crucial to evaluate the suitability of higher protection levels decided on the basis of national-scale criteria.

3) We have worked in the Città di Castello – San Sepolcro seismic gap area. We reconstructed two sections across Val Tiberina to account for lateral variations in width and depth of the valley. We also set up a procedure that, following the approach of Pergalani et al. (2000) determines the response spectral increment at uniform probability due to the site stratigraphy. We are presently working on numerical modelling and hazard parameters estimate.

Tsunami hazard in Italy (task 3.3)

The working group of Task 3.3, formed by INGV and University of Bologna, is involved in the realization of a map of tsunami hazard. The selected area for the investigation is the western Sicily and the Tyrrhenian coasts of Calabria, one of the most interesting areas from the tsunamigenic point of view. During the second year of the project the group concluded the research of both bathymetric and

geomorphological data for the studied coasts and most of the collected maps have been digitized. A detailed study of the 1693 tsunami has been carried out, in order to examine what would be the impact of a similar event today. In particular, a detailed historical reconstruction of the coastal urbanization has been done, to define the real inundation map. On the basis of this reconstruction and by means of up-to-date thematic territorial maps (cadastral maps, town-plans, country maps, etc.) some structures to be considered “ weak points” in case of inundation have been pointed out.

In addition, the working group has focused the attention to the simulation of tsunamis of the Messina Straits and to the study of methods for the computation of run-up and draw-down of tsunami waves. As regard the simulation, the 1908 Messina tsunami has been examined carrying on researches on the generating fault. Numerical simulations of the tsunami have been done and, in this aim, a new numeric mesh with triangular elements has been produced by means of a newly developed mesh building code. Results show that the faults proposed in literature on the basis of seismological, geomorphological and geodetic elements cannot explain the tsunami experimental data. A generating fault elongated towards south in the Ionian Sea at least till the latitude of Giardini Naxos, produce a tsunami more in agreement with the observations (Tinti ed Armigliato, 2003). This conclusions confirm the previous studies on this tsunami carried out by the same authors (Tinti e Armigliato, 2001) and recent studies based on the joined analysis of seismological and geodetic data. Another important element of this research is the study of the relation between the seafloor deformation and the tsunami generation. For the earthquakes occurred in the Messina Straits the theoretical model of Okada, normally used for the computation of the seafloor displacements produced by earthquakes, is not adequate because it assumes that the medium is homogeneous and delimited by a plane surface. Therefore, a specific study has been carried out in order to evaluate in which measure the superficial topography of the source area can affect the computation of the seafloor deformations responsible for tsunami generation. For this aim preliminary studies have been done by using a finite elements code to calculate displacement and stress in an elastic medium. This code has been developed by the group of University of Bologna and it has been applied to the study of the 1997 Umbria-Marche seismic sequence. The effects along some profiles orthogonal to the generating fault of the Messina tsunami (Capuano et al., 1988) have been calculated. The results confirm that the superficial topography characterized by strong gradients (in a few km there are Sila mountains in the southern Calabria and depths greater than 1000 m in the Messina Straits) strongly affects the displacements computation (Armigliato and Tinti, 2002).

The study of the tsunami propagation close to the coast has been carried out by means of analytical methods, by generalizing the classic solutions computed in 50' and 60' by Carrier and Greenspan for the shallow-water non-linear equations. Exact solutions relative to initial perturbations have been found: these solutions are similar to those generated by earthquakes with source area located near the coast. This study is now going on and till now it has been possible to demonstrate that, in this conditions, the formula proposed by Synolakis (1987), widely used for run-up evaluation, cannot be applied if the generation fault is close to the coast (Tonini, 2002).

Time-dependent hazard maps (task 3.4)

With respect to the three goals of task 3.4, the activity of year 2 can be summarized as follows:

1) Two families of probabilistic models have been studied; renewal processes and stress release processes. The first ones have been applied to four test zones of Italy: Friuli, Umbria, Irpinia and Stretto di Messina. The elaboration are based on CPTI catalogue, SZ4 zonation and earthquake with $M_a \geq 4$. For each zone the exceedance probability, conditioned to the time t_0 elapsed since the last event has been evaluated.

The mixture Exponential+Weibul shows for Friuli a possible time-magnitude correlation; Umbria a poissonian tendency; Irpinia a bi-modal weak tendency; Stretto di Messina a bi-modal strong tendency.

The second class of stress release models has been applied to Calabrian arc region and Irpinia-Sannio-Matiese area (ZS4 sources {65, ... , 72} and {58, 62, 63, 64}). Different version of these models (a unique physical process acting on a region, independent different processes, linked interactions between zones) have been studied. Open problems are where it is realistic to apply these models; the choice has to be driven by geologic considerations but also has to take into account the available observations with respect to the number of parameters that have to be calculated.

2) Concerning the validation procedures, a careful comparison between possible models connected with the physical knowledge of phenomenon, the statistical investigations and the awareness of the problems connected to the use of a given probabilistic model, represent a possible models' choice. The research has been applied to estimate constant values, such as the PGA of a site corresponding to long return periods. It is in progress for values that are variable in time, such as the hazard rate in the modelling of renewal processes.

3) The integrated model for SHA has been based on the data available at this stage, but it is flexible to the introduction of new knowledge. It is built on different levels of source models, treated in a logic tree structure. All the hazard maps are referred to the traditional $T=475$ years period, using literature PGA attenuation relationships from Ambraseys et al. (1996) without standard deviation. This choice enables us to compare the present results with the previous ones; in the final maps the attenuation laws obtained by Task 3.1 will be used.

Background level – The low seismicity level ($M < 5.5$) has been characterized on the instrumental catalogue 1981-1996 developed in the frame of the previous GNDT projects.

DISS level – Sources of Database of Potential Sources have been taken as they are, accepting the hypothesis of the project's participants that they are sources with known geometry and characteristic earthquake behaviour. Problems in the estimate of mean return periods will be faced with people working in the GdL 1; Other problems, dealing with the partial overlapping of sources, or with the geometrical meaning of the worse historical data (circular areas), not yet introduced in the present maps. DISS sources are separated into historical and geological sources; time-dependent tests have been tried up to now only on the second ones, and do not appear in the logic tree structure. The final map exhibits a spotty character with

relevant contribution of the background level prediction. The use of geodetic observations to balance the total moment release is presently under study.

Conclusion

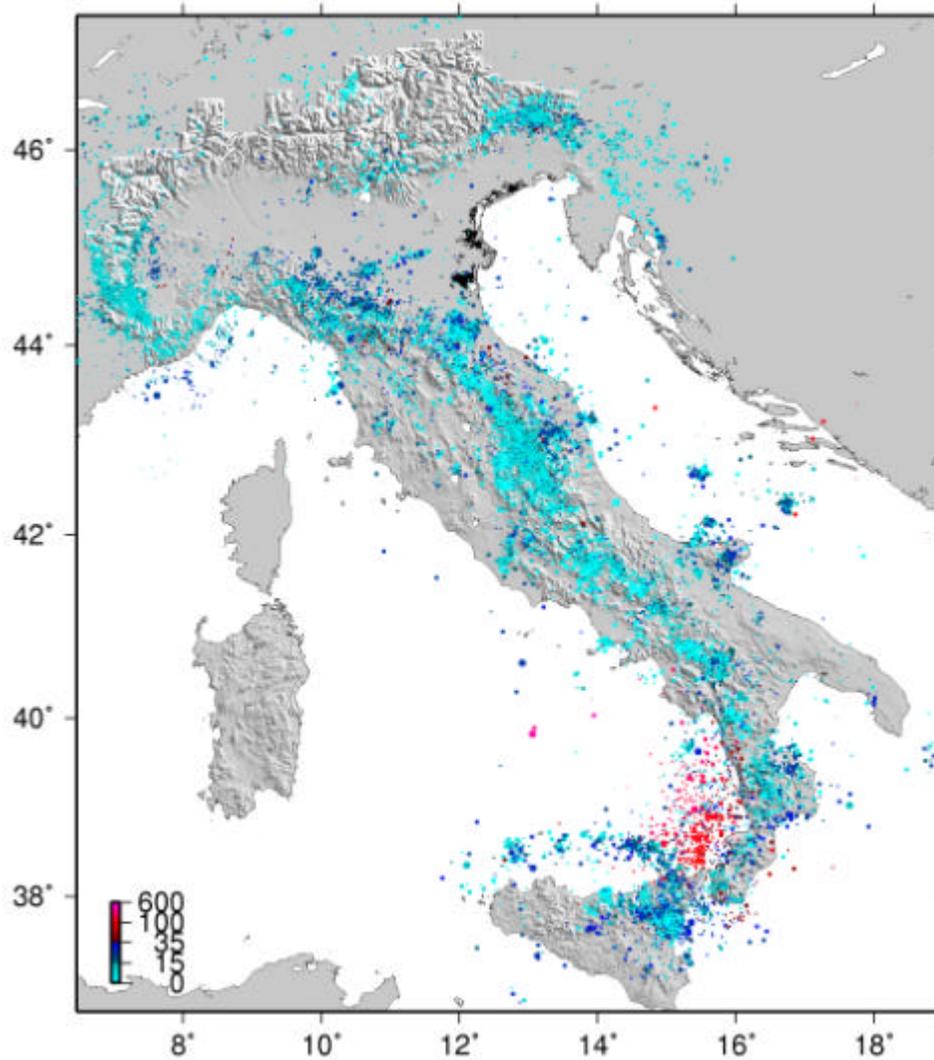
At the end of second year, the foreseen objectives have mostly been reached. Among them, an updated version of the Database of Italian Seismogenic Sources (DISS) with several new entries in poorly known areas. The review of historical reports has pointed out some previously unknown strong Apenninic earthquakes. Also the detailed study of two areas identified as potential seismic gaps has proceeded with the joint analysis of different methodologies. An important constraint to the seismogenic model of Italy is coming from original results of GPS remeasuring of old ('800) IGM triangulation network, which provided interesting results on the geodetic strain in the Apennines and in Sicily. These estimates will be used in the third year of the project to constrain the hazard maps. Another original product of the second year activity is an updated integrated catalogue of instrumental seismicity that contains more than 70,000 located earthquakes and shows nicely the characteristics of the seismic deformation in Italy. In parallel, a database of P-wave arrival times from active source experiments was prepared, and the joint analysis of earthquake and shot data to constrain better crustal velocity models and 3-D locations has already started. Moreover, a new seismic zonation of Italy has been sketched, based on the data sets from the different tasks of the project: it will be used for "conventional" hazard maps. Significant progress has also been done for determining regional attenuation laws, using huge sets of weak- and strong-motion waveforms. The results show widely varying characteristics of wave propagation throughout Italy, which have a strong effect on ground shaking at regional distance. In this year the whole set of more than 8,000 forms for the rapid evaluation of local geology effects was sent to the Italian Municipalities, and at present about 23% of forms came back. In this field, a procedure was also set to build, from a national map of "hard rock" PGA, the EC8 elastic response spectra (pseudo-acceleration) taking into account the simplified geologic classification obtained within the project from the 1:500,000 digital geologic map of the whole Italian territory.

Significant progress was also made for determining a tsunami hazard map for Italy, focusing in year 2 on Calabria and Sicily, both with original data and through numerical simulations.

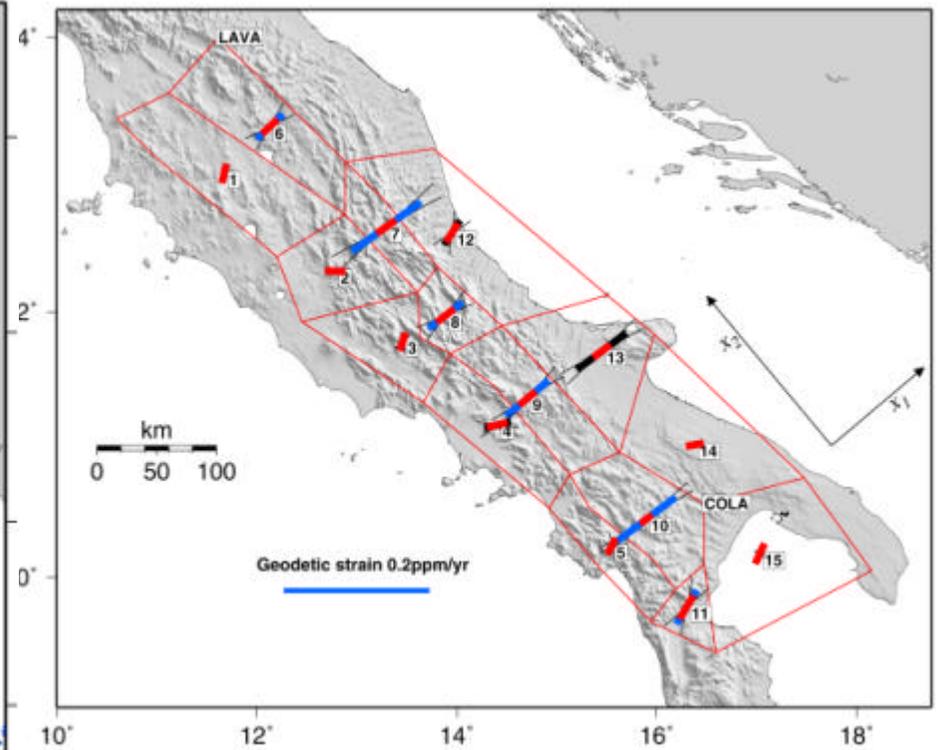
In the time-dependent hazard evaluation, probabilistic models were applied to some sample areas, testing the hypothesis of both renewal processes and of those accounting for the whole seismic history of the region. An original, although preliminary, integrated model of seismic hazard was obtained using both diffuse seismicity and mapped faults from DISS. The hazard map obtained in this way, which will be tested and improved during the third year thanks to the seismic and geodetic data collected during the project, is less smooth than usual hazard maps, also enhancing the relevant effect of background seismicity in some areas.

At the start of third year, almost all the data sets collected and organized by the project are available. They will be used to build or refine both conventional and time-dependent hazard maps, which represent the final goal of the project. To do so, the GIS specifically developed under the project will be used, allowing to show and compare easily the different data sets.

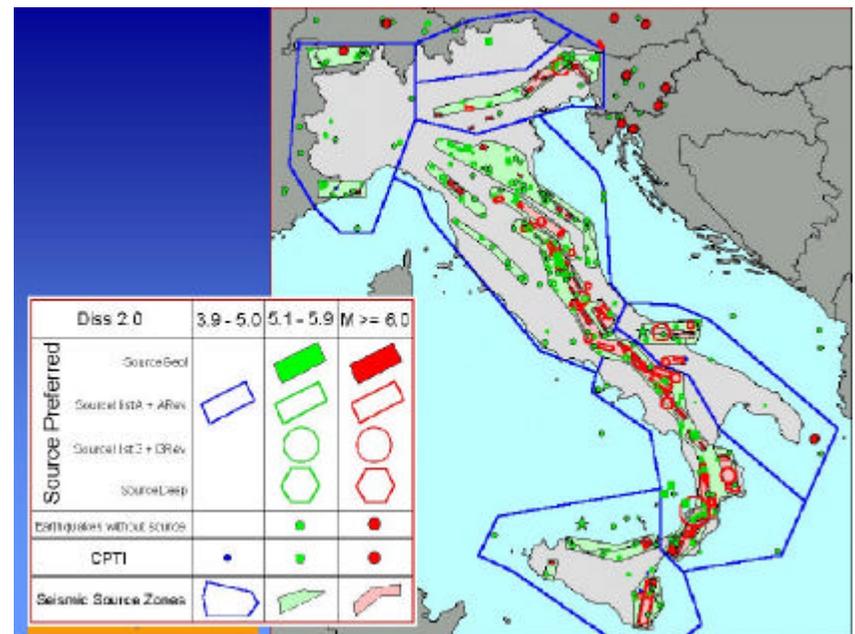
a)



b)

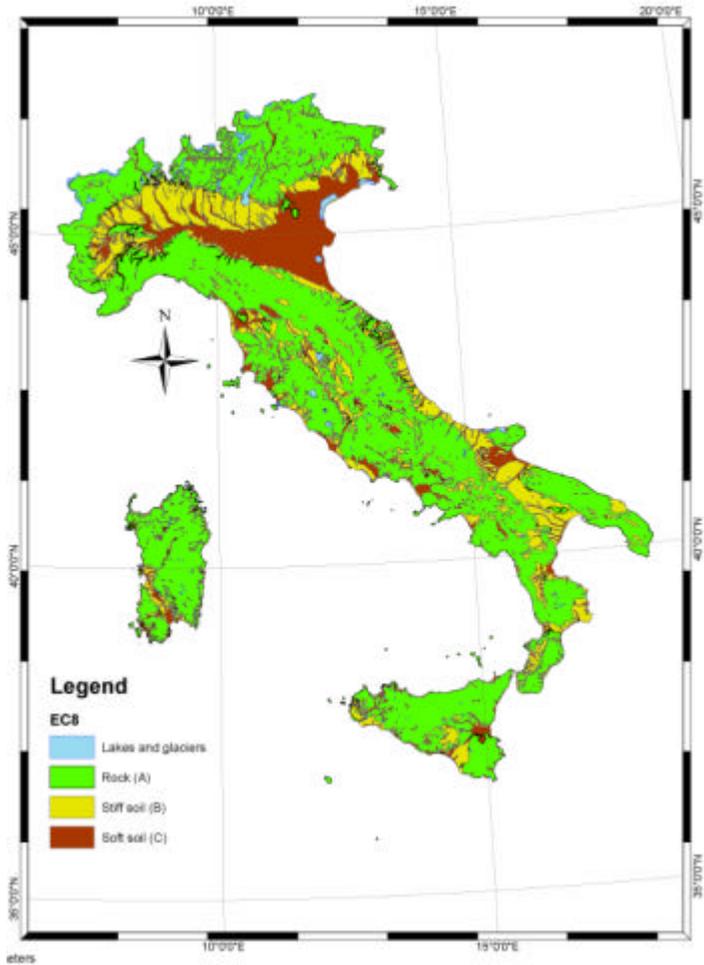


c)

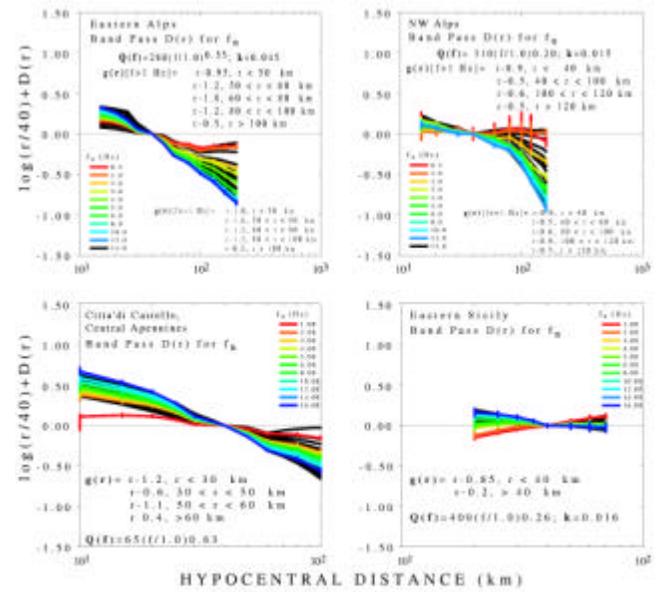


a) Epicentral map derived from the integrated instrumental catalogue 1981-2002; b) Geodetic shear strains (blue=extensional; black= compressional) plotted in the principal strain rate axes direction; c) proposed national seismic zonation from historical seismicity, instrumental seismicity and the DISS catalogue

a)

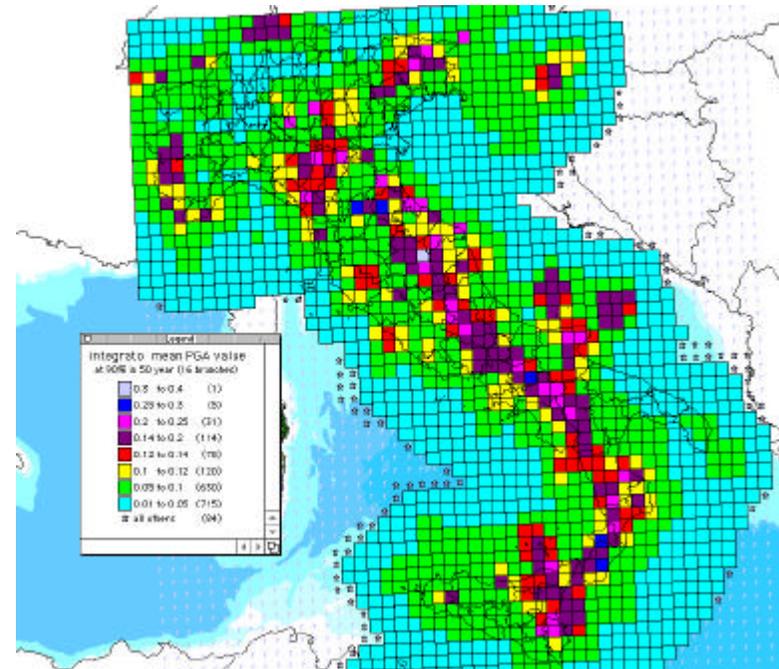


b)



$$D(r, r_{ref}, f) = \log g(r) - \log g(r_{ref}) - [\pi f(r - r_{ref}) / \beta Q(f)] k$$

c)



a) National geological maps in agreement with EC8; b) Regional attenuation laws for Eastern Alps, Western Alps, eastern Sicily and central Apennines; c) 90% PGA (g) probability using Ambraseys et al. (1996) attenuation relation. Seismicity from CSTI and historical and geological seismic sources from DISS