Agreement INGV-DPC 2007-2009

Project S1: Analysis of the seismic potential in Italy for the evaluation of the seismic hazard

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http://groups.google.com/group/INGV-DPC-2007-S1
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(public)

SCIENTIFIC REPORT - II PHASE

May 1st, 2009 – May 31th, 2010

Contents

Section 1: Report on the project by coordinators

Results of the project: general

The project S1 was aimed at (a) collecting new data and to update the existing databases needed to quantify seismic hazard; (b) promoting new studies on specific fields of knowledge and less-explored areas of Italy; (c) testing new approaches to evaluate seismic potential; (d) bounding slip rate values to use within probabilistic hazard estimates; and (e) preparing the way towards a future seismic hazard map of Italy. It was designed with three scientific parts – nationwide basic data, rheology, and field studies – and implemented into four tasks: 1) earthquake geodesy and modeling, 2) seismological data and earthquake statistics, 3) earthquake geology, and 4) tsunamis.
Although with many difficulties and some delay, described in the appropriate section, all the above objectives have generally been accomplished.
New observations were collected through original fieldwork and more sophisticated analyses were performed on existing data. Datasets needed for the seismic hazard estimates were updated at various levels by reducing both epistemic and aleatory uncertainties. New studies were carried out on specific fields of knowledge, e.g. addressing the repeatability of geodetic and stress data measurements or the seismogenic behavior of misoriented faults. Studies on less-explored areas were stimulated, and faults, whose seismic potential was not previously accounted for, were mapped and/or parameterized in the Ionian and Adriatic Seas, in Calabria, Sicily and the Southwestern Alps. Independent approaches to evaluate the seismic potential were tested, and a large effort toward homogenization and verifiability was made. The substantial improvements of nationwide datasets and understanding of the tectonic processes in large areas of the country set the basis for a significantly better assessment of seismic hazard.

Time-independent earthquake rates

Most of the RUs results were dedicated to improve specific aspects of the earthquake rates. Task A allowed determining the geodetic strain rates by means of independent approaches. Task C improved the parameterization of seismogenic sources, and reduced the epistemic and stochastic uncertainties. From the point of view of a national hazard map, the study of the less known areas was favored. A set of tests to validate the seismic source model of the DISS were designed, thereby providing a logical framework to address the seismogenic source model tectonic reliability (Deliverable D3.01.5). Task B contributed to reduce the uncertainties of the seismological data and to upgrade the Cpti10 historical earthquake catalog.
We present here (i) observed seismic moment rates (ii) predicted moment rates as derived from geodetic strain rate, geological data, block modeling and from finite element modeling, and (iii) predicted earthquake rates, based on average predicted moment rates and ZS9 parameters (see, e.g., Figure 1 for the Messina Strait). The rates presented here (Deliverable DT.01.2) have to be considered as an example of integrating different methods (e.g., GPS, Figure 2) and give a basis to compute uncertainties. The differences between the different approaches were discussed in a specific report (Deliverable DT.01.4). The brittle-ductile transition used in Deliverable DT.01.2-3-4 is the same and is shown in Figure 4.

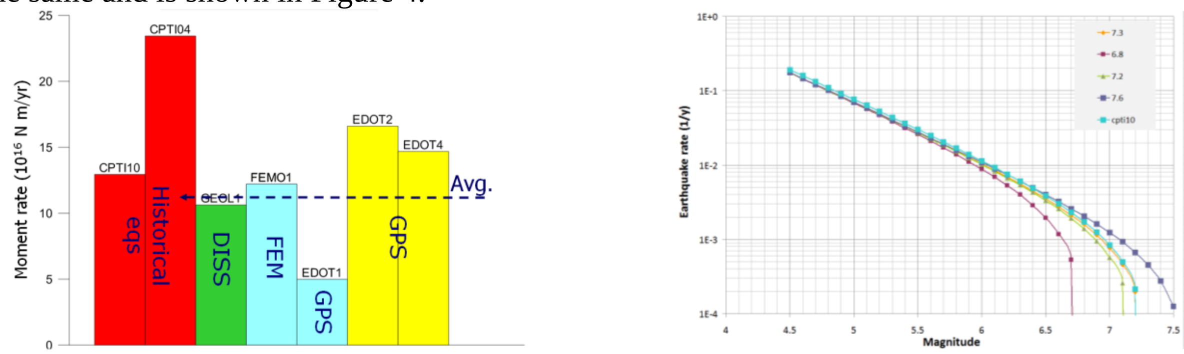

Figure 1: Moment rates estimates for the Messina Strait (left) and predicted earthquake rates (right).

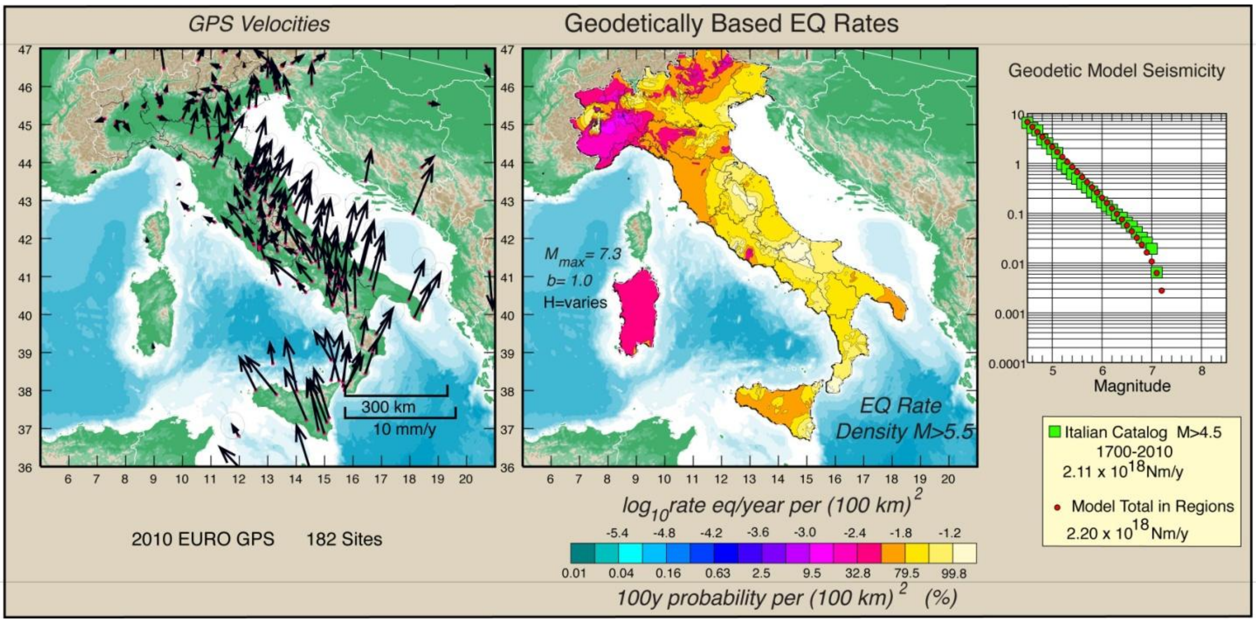

Figure 2: (Left) Italian geodetic site velocities with respect to Eurasia (RU 2.04-Devoti). Note the clear change in directions of sites east and west of the Apenines. (Right) Geodetic earthquake potential models for M>5.5 for b=-1.0 and M_{max}=7.5. Because moment is conserved, the choice of M_{max} affects predicted earthquake rates. M_{max}=7.3 fits well the historical earthquake rates (green squares).

Time-dependent probabilities

The RU S.02 has given a contribution towards long-term seismic hazard through two stochastic tools: self-correcting models and renewal process, both combined with the geological data base DISS, version 3.0.2.

In the Self-correcting models, different versions of the stress release model and of a new point process model based on the slip rate have been analyzed. Their conditional intensity function – instantaneous occurrence probability (= hazard function) have been estimated (deliverables DS.02.1-2). The probability distribution of the time of the next event has been simulated for each model and for each macro-region through a nonparametric kernel method (deliverable DS.02.4) by inverting the corresponding cumulative intensity function (integrated hazard function). The Bayes factor as quantitative measure of the evidence in favor of a model has been evaluated. In addition the stationary Poisson process has been considered as limit case (deliverable DS.02.5).

In the Renewal process, a three-step procedure consisting of exploratory analysis, prior assigning and estimation constitute is applied to each of the four data sets built by partitioning seismogenic areas. From each set, the estimate of a probability density of the inter-event time in each macro-region and a table with the occurrence probabilities in each seismogenic area within years 2012, 2022, 2032, 2052, 2102 have been obtained (deliverable DS.02.3).

Brittle-Ductile transition, seismic cycle, and fluids

RU T.01 and RU2.03 developed a model of the seismic cycle for extensional and compressional tectonic environments (Figure 3). The model predicts larger fluids discharge along a normal fault due to coseismic secondary porosity decrease, and vice-versa along a thrust fault. We tested the opposite scenarios with two examples from the Apennines and Taiwan. GPS data, fluid fluxes, energy dissipation and strain rate analysis support these contrasting evolutions. The model also predicts, consistently with data, that the interseismic strain rate is lower along the fault segment more prone to seismic activation, thus indicating that a low ratio of the geodetic to long-term strain-rate can be useful to map more hazardous areas. See Deliverable DT.01.3 for more details.

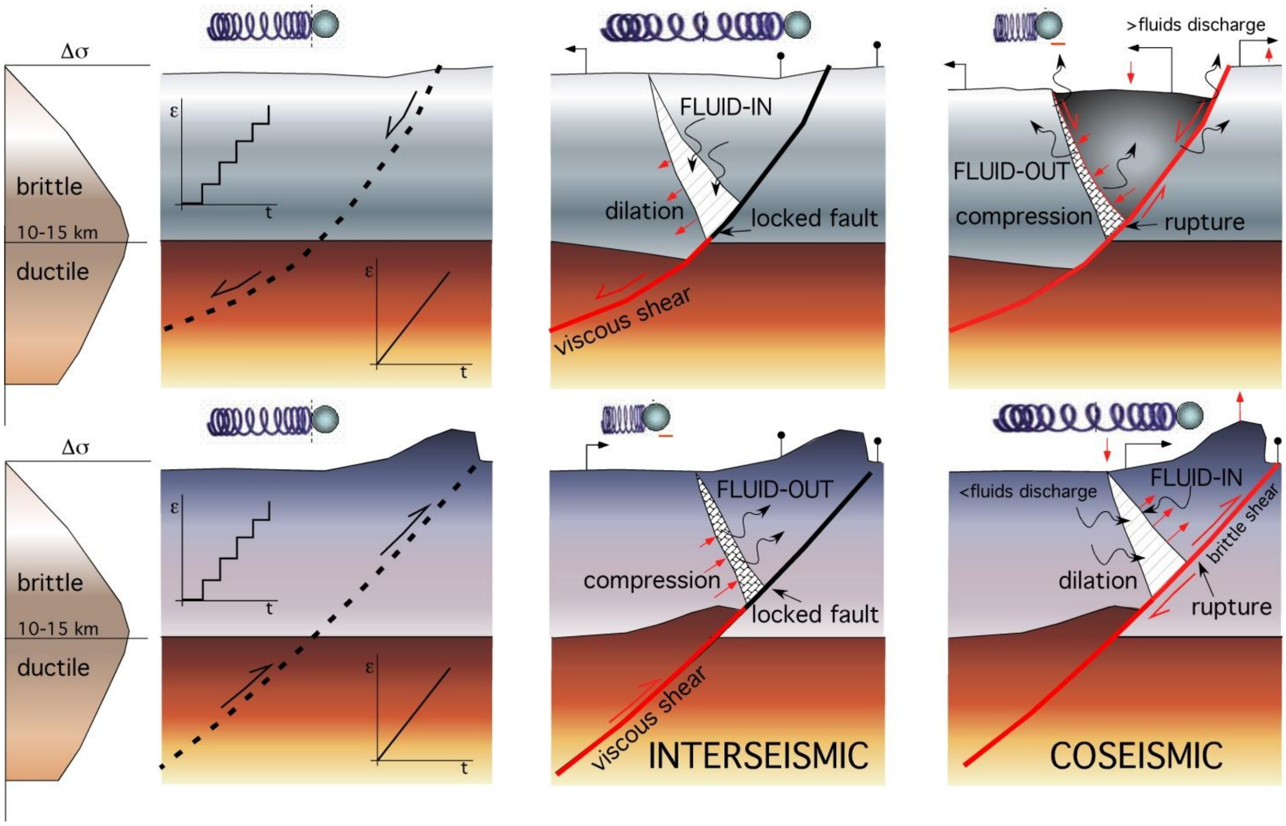

Figure 3: Assuming a steady stated strain rate in the ductile lower crust, stick-slip motion in the brittle upper crust, extensional and compressional faults generate opposite kinematics and mechanic evolution. In the extensional tectonic environment, the triangle of crust above the brittle-ductile transition remains "suspended" while a dilated area forms during the interseismic period. Once shear stress along the locked part of the fault becomes larger than fault strength, the hangingwall will collapse. Conversely, along a thrust plane, an area over-compressed separates the ductile shear from the overlying locked fault during the interseismic period. The hangingwall is expelled as a compressed spring during the coseismic period. Fluids discharge behaves differently as a function of the tectonic field.

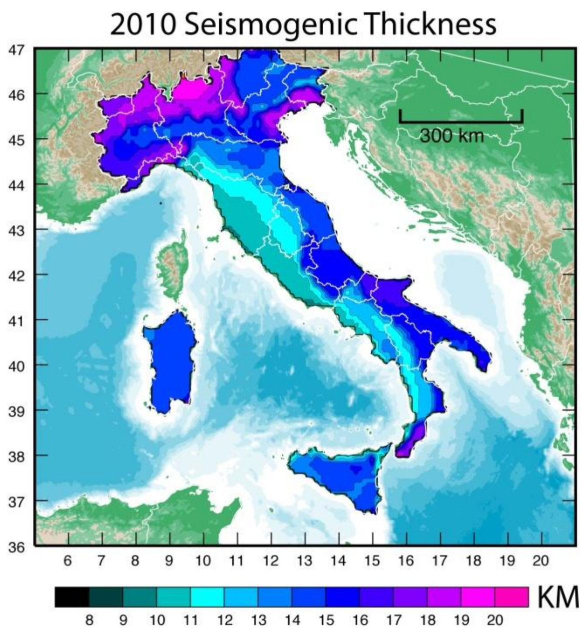

Figure 4: Seismogenic thickness for Italy based on average rheological properties of the crust (RU T.01).

Databases upgrade

DISS

The content of the Database of Individual Seismogenic Sources (DISS) was increased and updated (RU 3.12), and its structure and functionalities was improved for the benefit of its users. The documentation about the seismogenic sources based on geological/geophysical data was significantly increased. Each record of the database now has a "commentary" and a number of figures. References to scientific papers have also increased to over 2600, so that only a minimal number of records show less than 10 citations.

Areas with significant review of seismogenic sources are the Lombardia/Veneto, and the Abruzzo/Molise. The Dinarides contractional belt was extensively analyzed, including field studies. Several of these updates come from contributions of other research units of the project (e.g. 3.01, 3.07, 3.08, 3.10, and 4.01). The layer of Debated Seismogenic Sources have also been remarkably extended (26 new records) and improved.

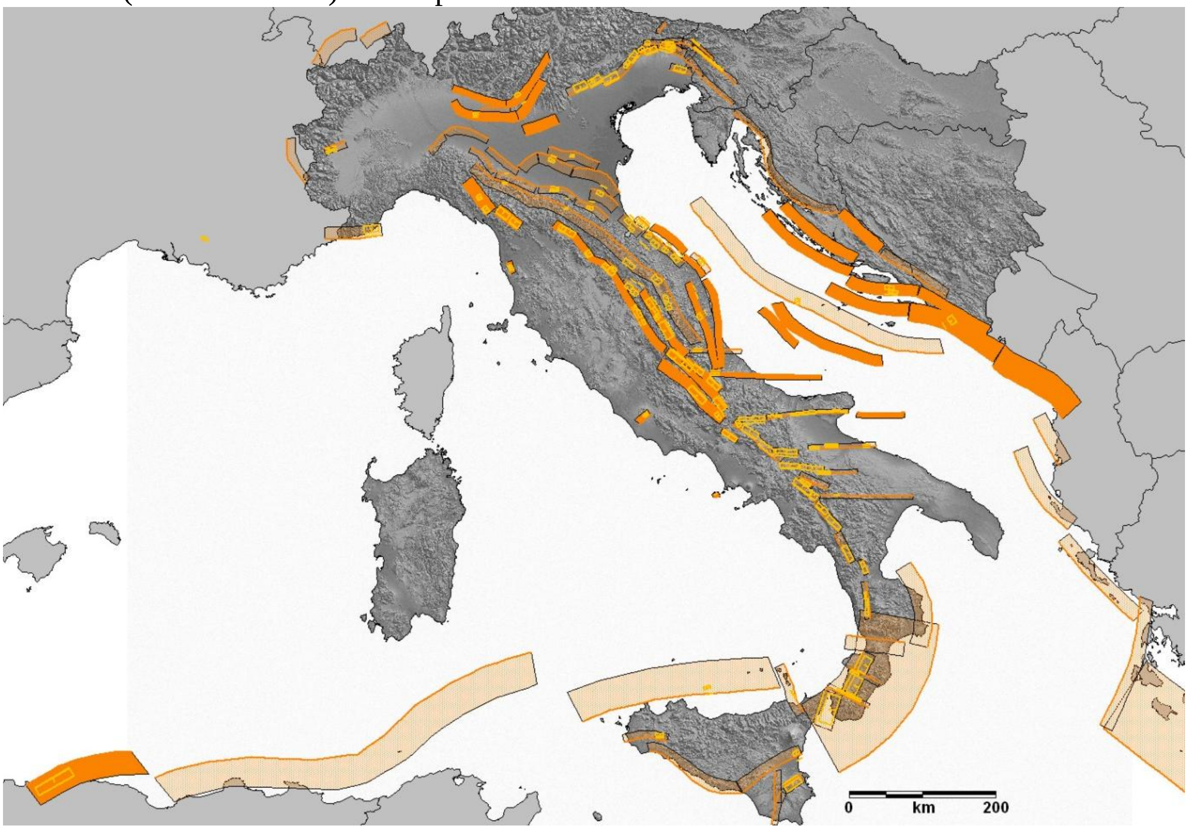

Figure 5: Individual Seismogenic Sources in yellow and Composite Seismogenic Sources in orange. Dark orange marks the new/modified Composite Seismogenic Sources.

Stress map of Italy

New stress orientation data were added to the Italy stress dataset. RU3.06 analyzed 64 well caliper logs, whose geographic distribution spans from eastern Sicily (13; Figure 6), Southern Italy (46), Adriatic offshore (4) and the Po Plain (1). Stress data along the Tyrrhenian coast are relevant as very few data existed before this analysis. Shmin orientations in this area are quite variable and seem to point out a general extension with a vertical σ1 and without a prevailing horizontal stress component. New borehole breakout data in Sicily confirm the NW-SE oriented compression direction in the Hyblean foreland and a 90° change in the orientations in the foredeep.

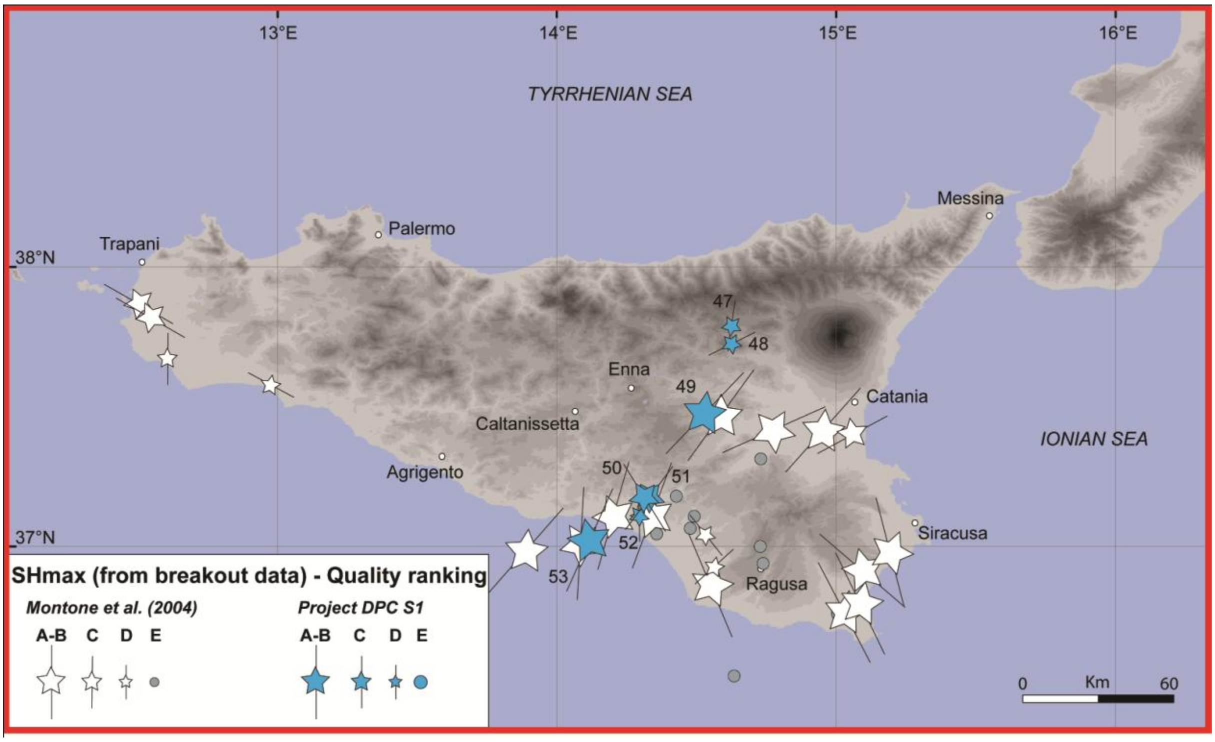

Figure 6: Present-day stress in Sicily from borehole breakout data.

Earthquake Mechanisms of the Mediterranean Area

The EMMA (Earthquake Mechanisms of the Mediterranean Area) database was improved by adding further mechanisms taken from the literature (deliverable D2.05.2; Figure 7). At present time it collects 12258 focal solutions, twice than the last public version 2.2 (Vannucci and Gasperini, 2004). As for the previous versions (Vannucci and Gasperini, 2003, 2004), the focal solutions are checked to verify the consistency among nodal planes and/or axes. When inconsistencies and misprints are found, these are corrected and recovered (if possible). The usable focal solutions are 11864.

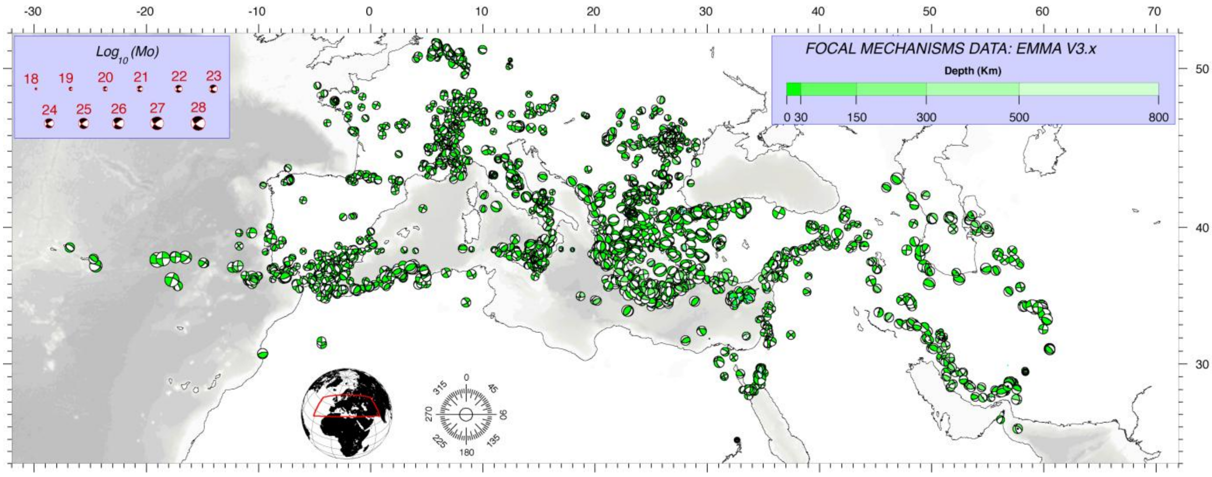

Figure 7: New focal solutions added to EMMA database.

Catalog of Italian Seismicity CSI 2.0

Retrieving of phase arrivals from various seismic networks, merging the data and associating the phases allowed producing the seismic catalog for years 2003-2007 (Figure 8). The phase association was performed after developing specific program codes. The location strategy pursued in the preliminary version of the catalogue, i.e., the multiple location approach with different initial parameters, was abandoned to favor a 3D earthquake location based on a high resolution 3D regional velocity model produced by UR 2.02. The tomographic inversion code SimulPS14 was used to locate earthquakes in 3D. ML computation is still in progress; Ml based on regression law by Castello et al. (2007) is attributed from durations retrieved by bulletins of regional and national permanent seismic networks, when they are available. A second preliminary version of the 2003-2007 update of CSI 2.0 (Deliverable D2.01.1) that does not include the Ml magnitudes from SWA waveforms but those based on regression laws has been delivered for beta-testing.

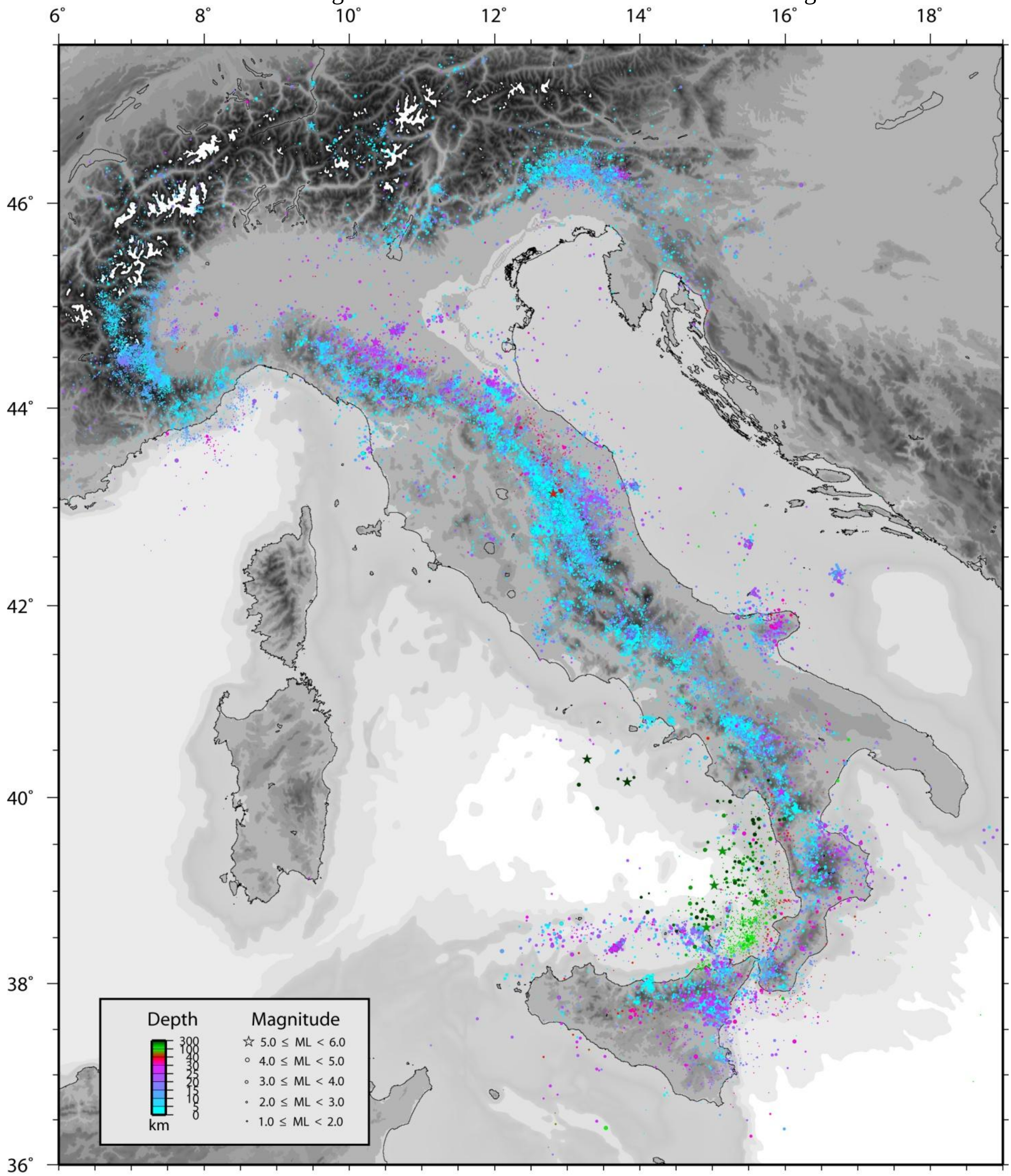

Figure 8: 2003-2008 Italian seismicity map from CSI2.0 update, 2008 data comes only from RSN-INGV seismic network. Magnitudes have been estimated from preliminary ML-duration regression.

Contribution to CPTI10beta

The computation of empirical relationships between moment magnitude and other types of magnitude was performed by RU S.01. The obtained coefficients were used to compile a database

of 669 homogeneous moment magnitude estimates for earthquakes occurred in the Italian region from 1901 to 1980 that also include 421 instrumental locations derived from the literature and from international agencies (ISC, PDE etc.) that have been checked for reliability (deliverable DS.01.1). These data contributed to the last version of the historical catalog CPTI10beta recently released by the INGV for beta-testing.
Boxer code was notably improved by introducing: *i*) 6 new methods (using the radiation center approach, i.e. using an attenuation law) for the location of the macroseismic epi/hypocenter beyond the "classic" approach (barycenter method) of the version 3.3 (Gasperini et al., 1999); *ii*) a new method for computing the magnitude, also based on an attenuation law; *iii*) assessment of uncertainties of all the computed parameters using both formal methods and the bootstrap approach (deliverable D2.05.1). All the details for the methodology, as well as the discussion of the results are described in a paper (Gasperini et al., 2010) currently in press on the BSSA. A new version (4.0) of Boxer code has been released and distributed among a group of selected users for beta-testing.

Crustal and lithospheric structure of Central Mediterranean

A high resolution 3D velocity model of the lithosphere in Italy was produced from regional to local scale by integrating information from seismic tomography, surface waves, controlled source seismology and Receiver Functions (RU 2.02, 2.04, 2.01). The resolution of the new velocity models for the Italian region makes them suitable for use in routine seismological analysis. Both the quality of earthquake monitoring and the definition of earthquake source parameters definition will strongly benefit from this advancement.
The RU 2.02 obtained two updated P-wave tomographic regional models by adding 299,924 P-wave arrival observations relative to 7,236 earthquakes recorded in the period 2003-2008 to the previously inverted dataset, which included 165,000 P-wave arrivals. The additional events have been selected from CSI 2.0 (RU 2.01) with strict quality criteria. Model 1 has a grid spacing of 15 km and is computed for the whole study region whereas Model 2, that is calculated on a finer grid (10 km) is defined only for selected areas.

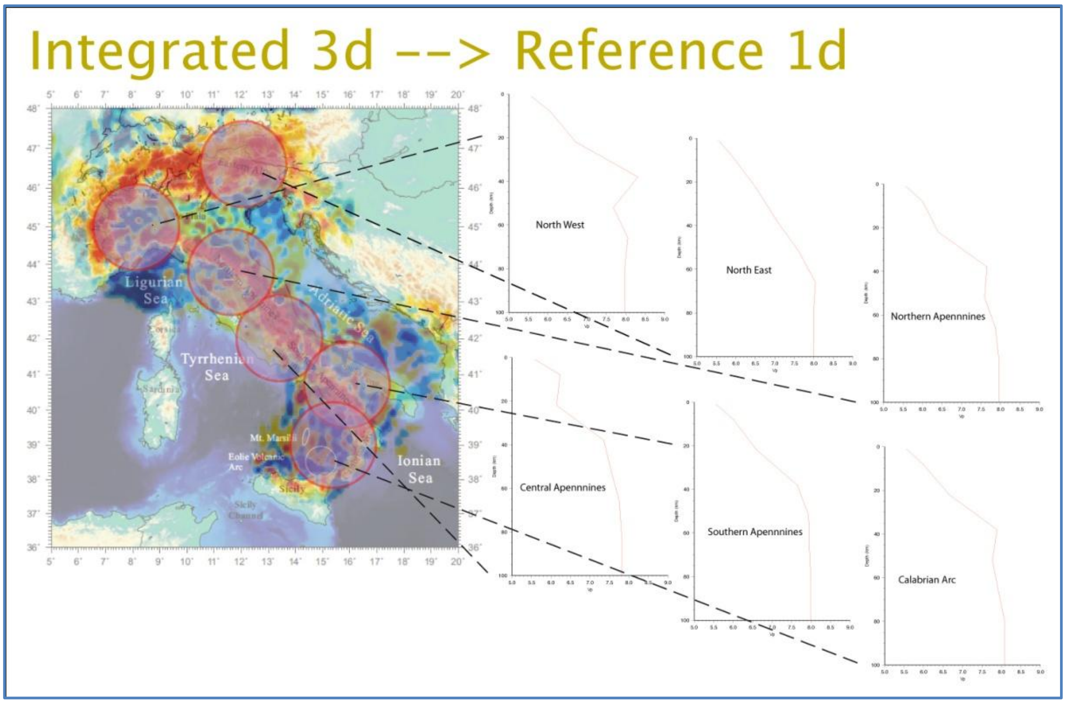

Figure 9: Best best 1D velocity model for sample regions. Such 1D velocity models can be used as reference models for specific regions in 1D earthquake location procedures and for new 3D local earthquake tomographic studies.

Surface wave tomography and non-linear inversion of dispersion curves allowed RU 2.04 to complete 1°x1° cell structural models for the whole Italian region. This effort is intended to extend the work done by Panza et al. (2007) for the Tyrrhenian Sea and surroundings. The RU used dispersion curves of Rayleigh fundamental modes along properly selected wave paths to obtain the S-wave velocities and the thickness of the layers by non-linear inversion. The available database is suitable to explore the S-wave velocity structure down to a depth of about 350 km (see, e.g., Table 1). Available interpretations of the seismic profiles that cross most of the Alps and adjacent areas along with information from literature served as *a priori* information to fix the thickness h and the V_p of the uppermost crustal layers, assuming that they are formed by Poissonian solids.

H	DENS	V_P	V_S	Q_P	Q_S	Z	Lon	Lat	Delta V_S+	Delta V_S-	Delta H+	Delta H-	V_P/ V_S
1.20	2.30	2.70	1.55	440	200	1.20	13.50	42.50	0.00	0.00	0.00	0.00	1.74
0.80	2.50	3.70	2.13	418	190	2.00	13.50	42.50	0.00	0.00	0.00	0.00	1.74
1.50	2.60	5.35	3.10	418	190	3.50	13.50	42.50	0.00	0.00	0.00	0.00	1.73
12.00	2.75	5.70	3.30	330	150	15.50	13.50	42.50	0.05	0.05	3.00	3.00	1.73
20.00	2.80	6.40	3.70	198	90	35.50	13.50	42.50	0.15	0.10	10.00	10.00	1.73
60.00	3.30	7.90	4.40	176	80	95.50	13.50	42.50	0.15	0.00	0.00	30.00	1.80
60.00	3.30	8.00	4.35	176	80	155.50	13.50	42.50	0.00	0.15	50.00	0.00	1.84
110.00	3.30	8.70	4.60	220	100	265.50	13.50	42.50	0.00	0.20	0.00	50.00	1.89
84.50	3.60	8.95	4.75	330	150	350.00	13.50	42.50	0.00	0.00	0.00	0.00	1.88

Table 1: Example of cellular database: structural model of cell b3 (13.5E-42.5N). H - Thickness (km); DENS - Density (g/cm^3); V_P - P-wave velocity (km/s); V_S - S-wave velocity (km/s); Q_P - Quality factor for P-wave; Q_S - Quality factor for S-wave; Z - Depth of the lowest interface (km); Lon, Lat - Geographical coordinates (°); Delta V_S+ DeltaV_S- - Variation range for Vs (km/s); Delta H+ Delta H- - Variation range for H (km). The boundaries between layers can well be transition zones in their own right. Black bold lines separate fixed ("a priori") and inverted layers; red bold line indicates the Moho.

The Moho map of Italy has been updated and stabilized by including new controlled source seismology data for the Western Tyrrhenian Sea, previously not covered by original data, and new data from a large number of Receiver Functions. A method developed by Waldhauser (1996) has been used to reduce the misfit between the data and the final interpolated surface using *a priori* information on the geodynamic setting of the study region. The Mediterranean region has been subdivided into 3 main polygons representing geodynamic provinces over which the interpolation was performed.

Slip rate of the seismogenic sources

Slip rate is a fundamental parameter in fault characterization which has a dramatic influence on probabilistic seismic hazard calculations. Slip rate is also very difficult to estimate. As of today, little attention has been given to differentiating slip rates in terms of the method used to estimate it, of the involved time window, and of the implicitly assumed behavior of the fault. This information will play a role when attempting to compare deformation rates based on instrumental data or models with geologic slip rates.

The slip rate table presented in Deliverable D3.01.2 is one of the first efforts made at developing a standardized method to collect geological slip rates and store them in a database. In this table slip rate was broken down into its basic geometrical, observational, and temporal components. We found the vertical component to be the most common.The structure of this table complies with prescriptions given in Basili et al. (2009), as such it can be easily incorporated as a relational table in the DISS. The usage of this standardized method will ensure that slip rate values are used in a homogeneous way in PSHA that use slip rate as input. This standardized method could be shared with other similar efforts at European (SHARE) and worldwide (GEM) scale.

In 71% of all cases slip rate was determined from observations at the ground surface. Only the remaining 29% of cases refers to slip at seismogenic depth. This suggests developing a strategy to correct most slip rate values for the behavior at seismogenic depth.

Slip rate values so far collected are very much heterogeneous also in terms of the observational scale which varies from decimeters (such as that of trench logs) to hundreds of kilometers (such as that of geodynamic models) and temporal scale which varies from few years (such as with GPS measurements) to few millions of years (long-term geological markers). We also noted whether the activity of faults refer to a reactivation of older faults with opposite movement type which may affect the frictional behavior.
For 87 out of 98 Composite Seismogenic Sources in DISS 3.1.0, the slip rate and fault kinematics were determined also by means of numerical modelling (Figure 10, RU 3.01 and 5.03). Slip rate average is 0.39 mm/yr, while the mean of the standard deviation is 0.26 mm/yr.

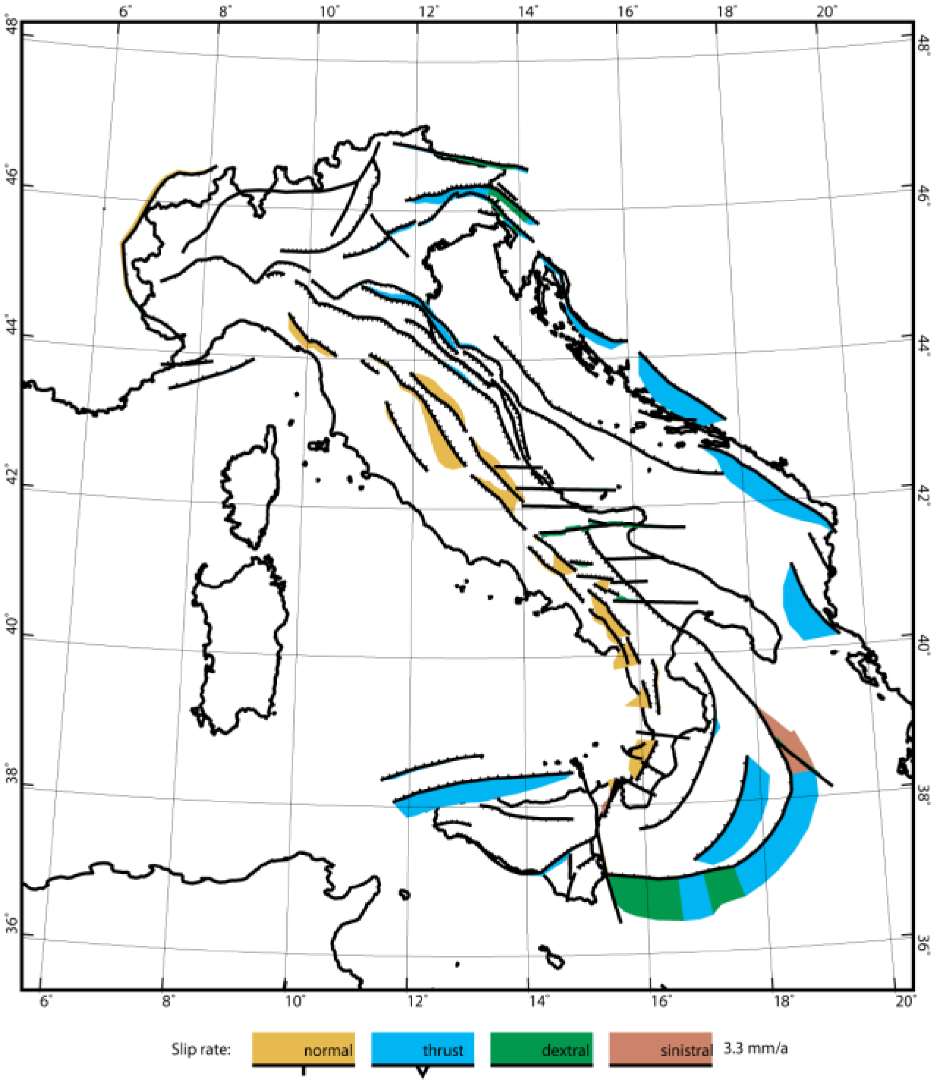

Figure 10: rates and fault kinematics as derived from numerical model (RU 3.01 and 5.03).

Geodetic analyses

Geodetic velocity field

To reassess the GPS velocity field of the entire Italian area, RU 1.04 processed all the available permanent GPS observations in the interval 1998-2009 using two different softwares (Bernese v. 5.0 and Gamit-Track v. 10.33) and hence obtaining two independent velocity fields. The analyses are based on about 400 permanent GPS sites supplied by EUREF (International GNSS Service), RING (Istituto Nazionale di Geofisica e Vulcanologia), ASI (Agenzia Spaziale Italiana), FREDNET (Istituto Nazionale di Oceanografia e Geofisica Sperimentale), ITALPOS (Leica),

Regione Puglia, Regione Friuli, Regione Lombardia, University of Perugia, University of Calabria (UNAVCO) and other universities and local authorities.
Estimates of the velocity field are especially robust as they take into account instrumental changes, annual sinusoids, sporadic offsets and outliers using specifically developed and well-tested software.
The comparison of the horizontal velocity fields estimated from the two independent time series (Bernese and Gamit) shows differences in the order of 0.6 mm/yr in the horizontal plane and 0.7 mm/yr in the vertical components (Figure 11). A comparison between the Bernese velocity solution of RU 1.04 and the velocity solution provided by RU 1.02 returned differences in the order of 1 mm/yr (Figure 11), hence higher than the Gamit-Bernese agreement, showing that a close interaction between analysis centers is strongly needed to improve the quality of the results.

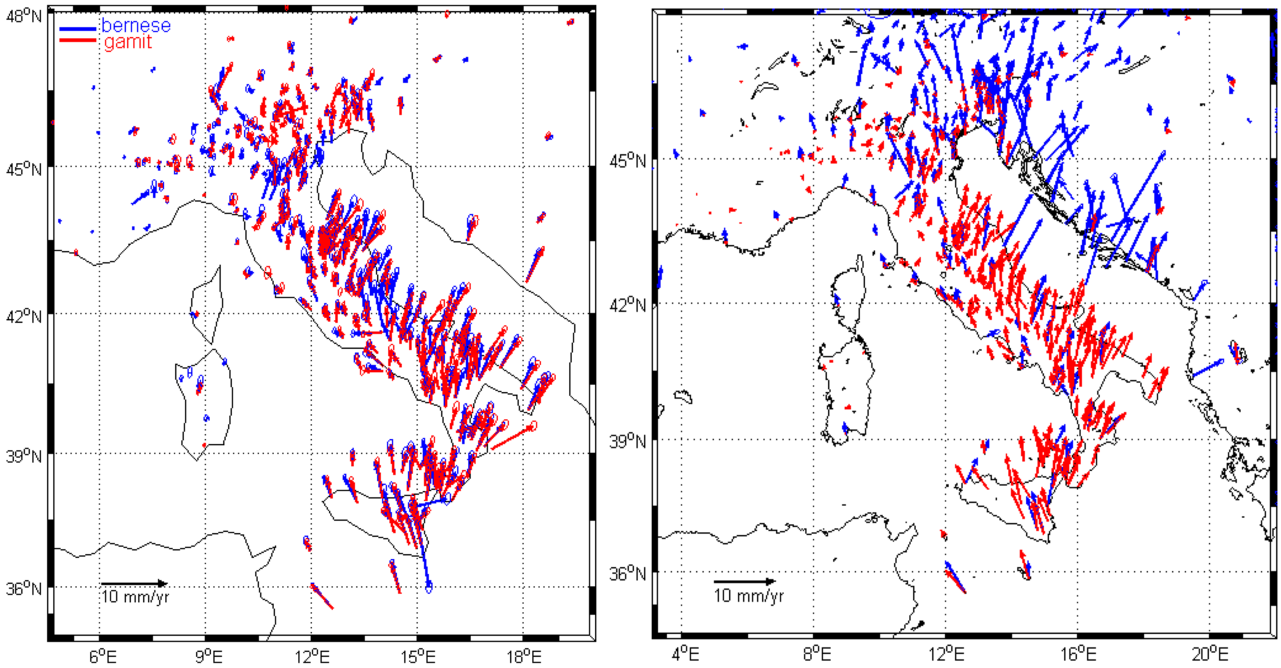

Figure 11: (Left) Comparison between the Bernese (blue) and Gamit (red) raw horizontal velocity fields with respect to the Eurasia fixed; (Right) Comparison between the RU 1.02 (blue) and Bernese RU 1.04 (red) horizontal velocity fields.

Strain rate

The combined solution in the Eurasia fixed reference frame shows clearly that the extensional belt running along the Apennines is the most significant tectonic feature of the entire Italian area. Typical values range between 20-60 nstrain yr^{-1} (Figure 12) although with variable magnitude along the chain. Significant shortening associated with pure compression is seen in the Dinaric Arc, in the eastern Alps and offshore north-west of Sicily.

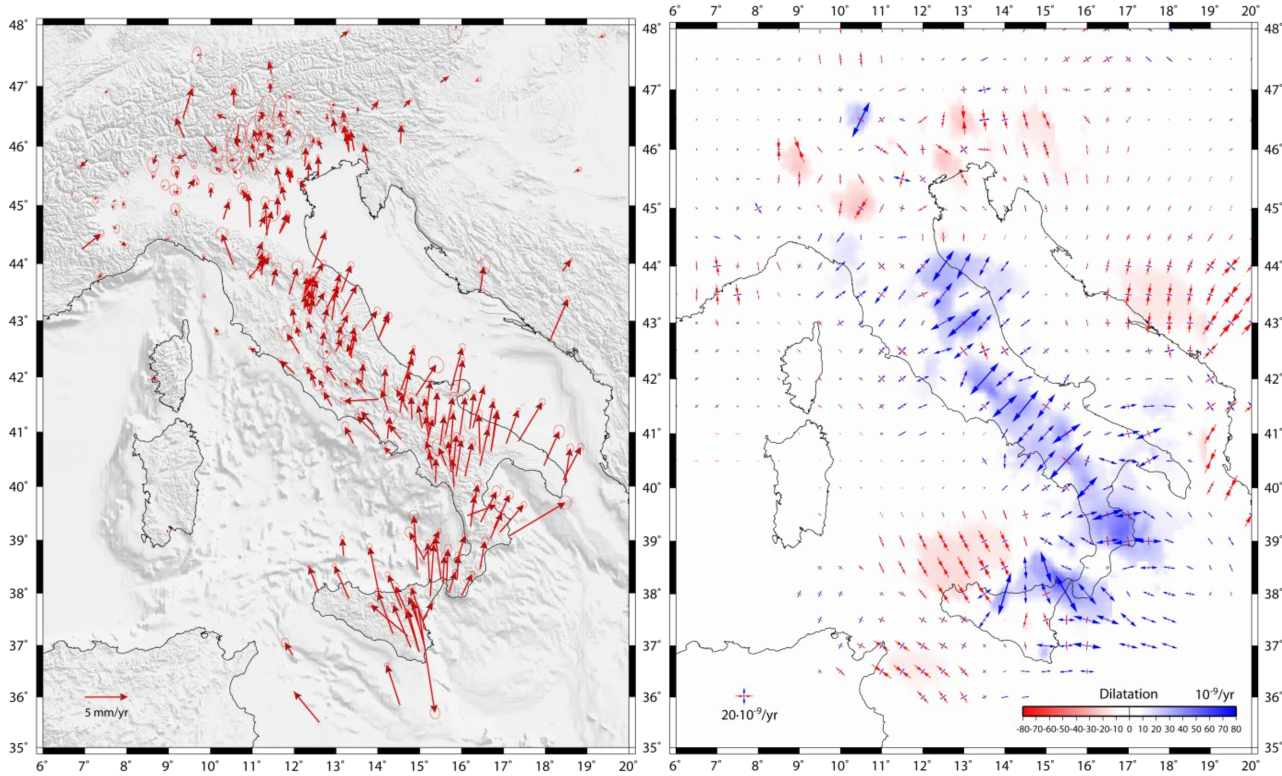

Figure 12: (*Left*) Combined horizontal velocities with respect to Eurasia fixed reference frame. A total of 287 sites with more than 2.5 years of observations have been selected. (*Right*) Principal strain-rate axes interpolated on a 0.5°x0.5° grid and two-dimensional dilatation rates obtained from the combined solution (Devoti et al. 2010).

The RU 1.04 also developed an iterative method to estimate the velocity field of a GPS network by adding recursively the daily coordinates. The velocity field is obtained as the solution of the restricted least squares problem.

A subset of sites of the combined velocity solution defines the fiducial network of the current solution. This network represents the best performing sites of the Italian area with at least 2.5 years of continuous observations and a formal error below 1 mm/yr in the velocity estimates. The fiducial solution is archived in a SINEX file (Deliverable D1.04.2).

Block Model

As an approach that is independent from the strain rate computation, RU 1.03 analyzed and interpreted the GPS velocity field of the Italian territory by means of block modeling. The region was subdivided into a number of fault-bounded blocks (block modeling); each block is then characterized in terms of rotation rate and the sense and magnitude of slip on the bounding faults. The block modeling approach used Composite Sources from the DISS 3.1.0 database to infer slip rates for individual faults. Even when all uncertainties and limitations are taken into account, the results of the analysis are very interesting and show slip rates averaging about 1 mm/y for the entire Italian peninsula, in agreement with results from field studies and from geodynamic modeling. The main results (Figure 13) are the Euler rotation vectors of the microplates and crustal blocks included into the analysis and the geodetic slip-rates of the faults surrounding the blocks (Deliverable D1.03.B1). Euler rotation poles are presented in terms of relative poles positions and rotation rates between blocks pairs. Fault slip-rates are presented in terms of dip-slip rates for dip-slip fault segments, and tensile-slip rates for assumed vertical fault segments. Vertical faults were used when no information, or debated information, are available from the DISS database.

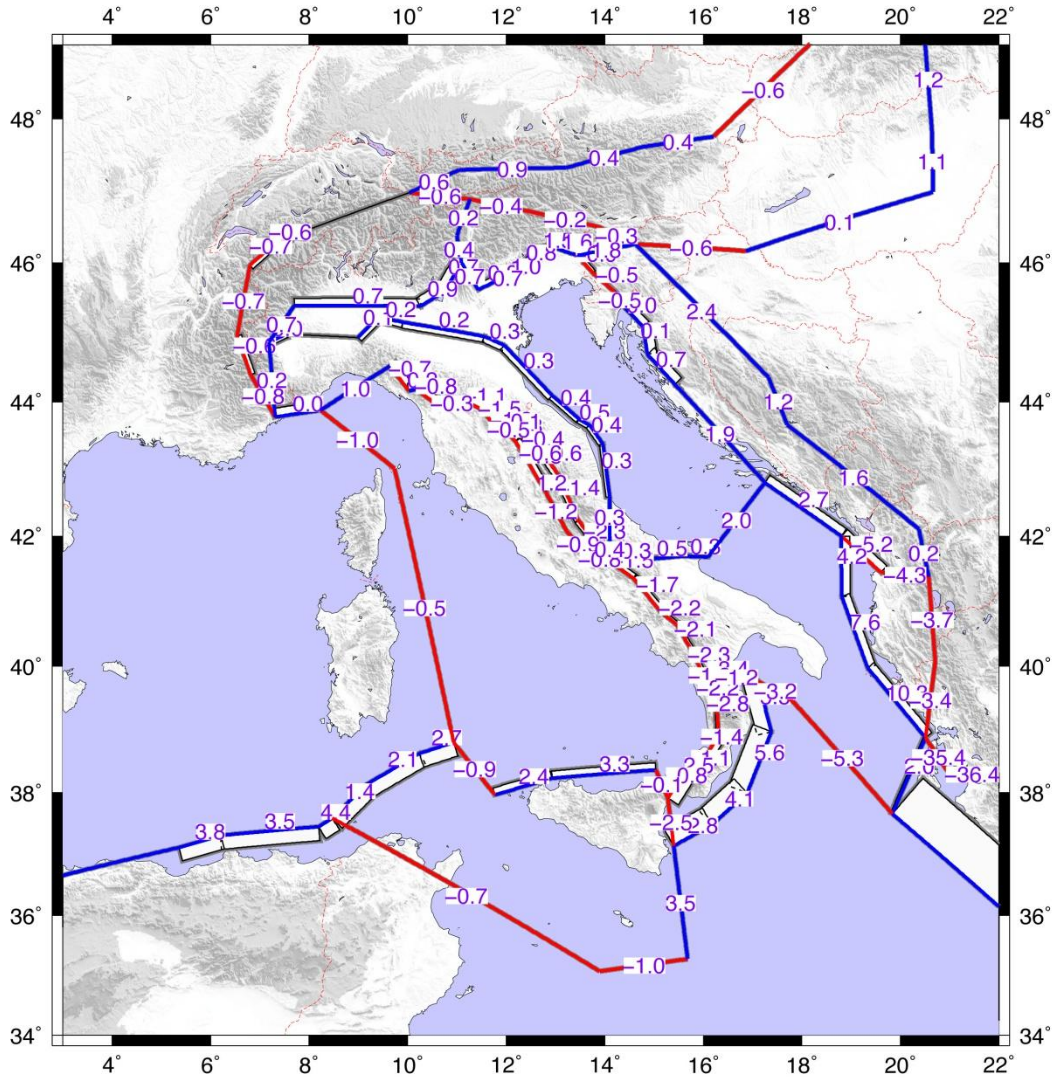

Figure 13: Blocks and block-bounding faults configuration (in blu and red) plotted over faults from the Geodynamic map of the Mediterranean. Dip-slip faults are plotted as grey box, being the box the surface projection of the dip-slip fault plane. Vertical faults are represented as lines. The colors represent the tectonic regime (extensional faults are in red, thrust faults are in blue) obtained from the inversion of the GPS velocities. Numbers reported on block-bounding faults represent dip-slip and tensile-slip rates from the block modeling (in mm/yr). The strike-slip component and uncertainties are in the deliverables.

Static stress drop

The maximum average stress drop which can be released seismically was computed by RU 1.02 in collaboration with RU 1.04 and RU T.01. This method is innovative in at least two aspects. One is that, to counteract the unavoidable incompleteness of the seismic catalogue CPTI04 and hence the inaccuracy of the seismic strain-rate obtained from a summation of the seismic moment, we assign a pair (a_s,b_s) of Gutenberg Richter parameters to each ZS9 and compute the seismically released strain rate with reference to the regional Gutenberg Richter law *N(m;* a_s,b_s*)* rather than the individual earthquakes recorded in each ZS9:

$$\dot{\varepsilon}_s = \frac{1}{2}\frac{\int_{m_{min}}^{m_{max}} N(m)A(m)u(m)dm}{\int_{m_{min}}^{m_{max}} A(m)T(m)dm}$$

The second innovative aspect is that we show that the seismic volume (A*T: area * height) releasing the strain-rate depends on an average, regional stress drop $\Delta\sigma$. This is in turn proportional to the mechanical work required to dislocate the faults present in each ZS9:

$$\underbrace{\Delta\sigma A(m)T(m)}_{change\ in\ potential\ energy} = \underbrace{\mu A(m)u(m)}_{mechanical\ work} \xrightarrow{yields} T(m) = \frac{\mu}{\Delta\sigma}u(m)$$

Hence the thickness of the seismogenic volume is proportional to the slip u(m) and the proportionality constant is the ratio between the shear modulus and the static stress drop.
If we impose that the seismically released strain-rate $\dot{\varepsilon_s}$ never exceeds, on average, the geodetic strain-rate $\dot{\varepsilon_g}$, then the average static stress drop of each seismic zone is bounded by the maximum value:

$$\Delta\sigma \leq \Delta\sigma_g \equiv 2\mu\dot{\varepsilon}_g \frac{10^{[a_{wc}+b_{wc}m_{max}]} - 10^{[a_{wc}+b_{wc}m_{min}]}}{10^{[a_s+a_{wc}+(b_s+b_{wc})m_{max}]} - 10^{[a_s+a_{wc}+(b_s+b_{wc})m_{min}]}} \frac{b_s + b_{wc}}{b_{wc}}$$

This maximum value depends on regional factors (the geodetic strain rate, the maximum magnitude, the Gutenberg Richter parameters (a_s,b_s), as well as on generalized scaling coefficients (the Wells and Coppersmith coefficients for the slip area and slip vector as a function of magnitude).
The results we obtain for the static stress drop indicate that the maximum static stress drop in Italy $\Delta\sigma_g$ ranges from 0.1 to 6 MPa, and is in most cases below 2MPa, in agreement with the independent seismological estimates of a dynamic stress drop. Values of $\Delta\sigma_g$ for all ZS9 are listed within RU 1.02 report.

Vertical tectonic rates

For the determination of apparent tectonic rates we can rely on 26 tide gauge stations along the Italian peninsula. RU 1.01 selected those stations in which the altimetric sea level rate exists, that is the stations in which the satellite track flies over the tide gauge station (or at least close to it) and in which the calculated altimetric trend is available. We obtain thus the apparent tectonic rates in 12 tide gauge stations, as simple difference between the sea surface height trend observed by altimeter and the sea level trend observed by tide gauge (Table 2).

Station	Apparent tectonic rate (mm/yr)	Error (mm/yr)	Distance (km)
Ancona	0,1	2,7	21
Bari	-2,2	1,7	24
Cagliari	-1,8	1,3	65
Carloforte	0,8	1,6	94
Civitavecchia	-0,4	1,5	31
Imperia	1,4	1,7	66
Lampedusa	-1,6	1,5	17
Livorno	2,9	1,9	37
Palermo	-0,8	1,4	44
Otranto	-1,9	1,1	50
Portotorres	5,0	1,5	37
Vieste	2,4	1,7	24

Table 2: Apparent tectonic rates in selected tide gauges stations. 1st column: station name; 2nd column: apparent tectonic rates in mm/yr (positive value = uplift); 3rd column: error in the rate determination; 4th column: distance between tide gauge and satellite observation point.

However, the apparent tectonic uplift rate do not necessarily coincides with the geologic tectonic rate due to the following:

1) the time interval used in our analysis is not comparable with that of geologically determined rates;
2) isostatic effects can influence the tectonic rates. They have not been introduced here;
3) we cannot exclude possible local effects due to ocean currents. Presently the knowledge on the currents in the Mediterranean does not allow this effect to be quantified. This could provoke differences in the sea level rates measured at the altimeter observation points, which dist from tide gauges between 17 and 94 km, and at the tide gauges.

Numerical models

RU 5.03 continued and improved the research activities carried out by the project S2 of the 2004-2006 INGV-DPC agreement, focusing on numerical modelling of deformation processes at the regional and national scale.
The RU initially gathered all the data needed to calculate the stress and strain regimes at national scale, including focal mechanisms taken from the EMMA database (RU 2.05), stress data from S_{Hmax} measurements (from Heidbach et al. 2008, and RU 3.06), GPS measurements from RU 1.04 and 1.02, heat flow data and geothermal gradient to estimate the strength of the lithosphere, crustal and lithospheric structure data obtained by other RUs 2.02 and 2.04. These input data were use to test and score the predictions of a dynamic model based on a code developed by Bird (1999) to predict velocities and stresses. Modeling follows the approach of Barba et al. (2008). The RU generated 970 “base models” for which the uncertainties of the analysed parameters are spread. The scoring datasets include the geodetic velocities, the azimuth of stress directions and the tectonic regime implied by fault plane solutions. The final average model shows lower misfits with respect to the year 2007 geodynamic model. In particular the best fitting model improves the misfit with respect to GPS measurements from 1.64 mm/a to 1.08 mm/a, making the misfit comparable with the RMS of the GPS measurements derived by different research units (RUs 1.02 and 1.04 returned differences in the order of 1 mm/a).
The RU also calculated slip rates and their standard deviations were calculated for faults located inside the stable area of the model. All faults falling in each Composite Seismogenic Source (CSS) of the DISS database (v. 3.1.0) (Basili et al., 2008) were also grouped and their slip rates were averaged to give the CSS’s slip rate. The slip rates have been validated by comparing them with geological values (in collaboration with UR 3.12). Model slip rates fall in the same range as geological slip rates, and the moment rate due to slip-rate represents nearly 50% of the whole deformation rate of the model. Such pattern of slip rates seems to be realistic, indicating that the model and the geodetic-geological data can be successfully integrated to give an independent set of results. The remaining discrepancies are believed to depend on the approximation of the used code (for example in the Po Plain area), or occur in areas for which DISS does not report any faults, such as Tuscany. The largest values are found for the Ionian arc (up to 3mm/y) and the Central Apennines (2 mm/y).

Significant advances in specific areas

The potential seismogenic structures located close to the coast and the offshore of the Italian peninsula are poorly known. All the research contributed to reduce the uncertainties in studied areas, and the details can be found in RU reports. Here we present significant findings, from Northern Apennines to the Calabrian Arc accretionary prism (Ionian Sea).
In the South Alpine chain, buried below the Po Plain post-glacial alluvial, the need to clarify the present day behavior of the E-W trending back thrusts (south plunging) was obliged bycollecting data at a very detailed scale in two sites: Monte Netto nearby Brescia and Borgo Vico in Como. Work in the Monte Netto site includes exploratory trenching, geophysical surveying, and geochronological analysis.One trench, Cava Danesi site, provided evidence for three

paleoearthquakes occurred between 45 ky BP and 5 ky BP, indicating that the thrust is active and seismogenic (RU 3.07). In the Lake Garda area, high resolution multi-beam bathymetric data were collected between San Vigilio Point and Sirmione Peninsula in order to recognize seismically-induced structures and deposits. Main preliminary results in interpreting data from this campaign suggest that a number of fault lines could be mapped and correlated with structures on land thereby providing new evidence of Quaternary faulting in this area.

Newly obtained seismic data in the Po Plain, together with existing geological and seismicity data, provided a 3D reconstruction of the basal detachment of the Northern Apennines accretionary prism (RU 3.10, 3.11). This reconstruction opens new questions about deep-focus seismicity in the area.

The study of coastal and offshore areas of Abruzzo and Marche confirmed the recent activity of crustal thrust faults (Figure 14).

An important result is represented by the structural maps in the central Adriatic off-shore that depict the location of individual thrust fault planes (RU 3.10). They give evidence for late Quaternary contractional deformation affecting the off-shore innermost thrust plane. Fault activity seems to decrease towards the external sector of the chain where, the identified several structures of the thrust system do not show evidence of deformation in the middle-late Pleistocene. These results provide insights into ITIS029 and ITCS008 seismogenic sources of the DISS.

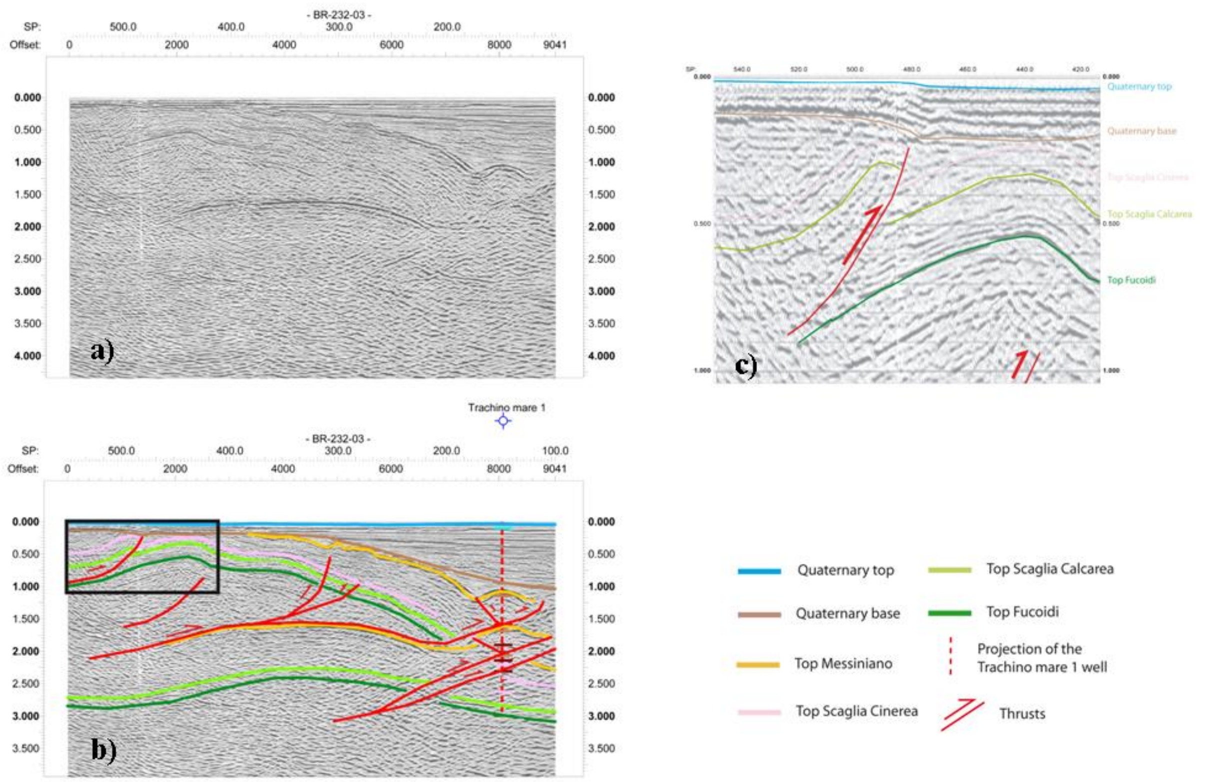

Figure 14: Seismic reflection profile BR-232-03, location in figure 1 and 2: a) uninterpretd, b) interpreted, and c) detail showing the deformation of the Quaternary sedimentary unit due to thrust activity

Results of high-resolution seismic stratigraphy conducted by RU 3.08 in the Adriatic Sea, south of the Gargano Promontory, yield evidence of activity younger than 5.5 ka along the entire length of the Gondola Fault Zone (GFZ). Detailed studies of the WNW-ESE portion of the GFZ were added during this project. Results indicate that in part of the fault zone, evidence of shallow faulting in recent sediments is less continuous than thought, which can be attributed to the different activity of the GFZ along its whole trace and the role of sediment deposition/remobilization and erosion by high energy processes typical of the deeper slope environment. Nonetheless, this part of the fault zone as-well exhibits recent displacements that correspond to dip-slip movements along WSW dipping fault planes. Along the entire length of the fault system pre-existing structures, and thus reactivation processes, play an important role.

RU3.04 work focused on quantifying Holocene uplift/subsidence rates along the Tyrrhenian and Ionian coasts of Calabria and discriminating between the regional (deep-seated subduction related) and local (crustal faulting related) components. They compiled a database of Holocene rates with a total of 61 sites, 16 of which studied in this project. Most of the new uplift rates exceed 1 mm/y (Figure 15). They also updated a previous compilation of Pleistocene uplift rates. Uplift data analyzed in the Sibari plain were carefully discriminated from local, compaction-induced, subsidence.

Figure 15: Holocene vertical displacement rates at the coasts of the Calabrian arc.

Assuming that sequences of raised shoreline can be generated by coseismic uplift, RU3.04 identifies four sectors of the Calabria coast where paleoearthquake could have occurred. Previously known sites combined with two more sites studied during this project yield a total of 10 paleoearthquakes in the last 5 ky, three of which correlated with historical events. Combining the analysis of raised Pleistocene terraces with geological structures mapping they propose five seismogenic shallow sources (5-7 km), capable of generating earthquakes up to Mw 6, in northeastern Calabria.

In the area of Crotone peninsula (Calabrian Arc), new geologic and instrumental (A-InSAR) data were used by RU3.01 to constrain tectonic rates (Figure 16 and Table 3).

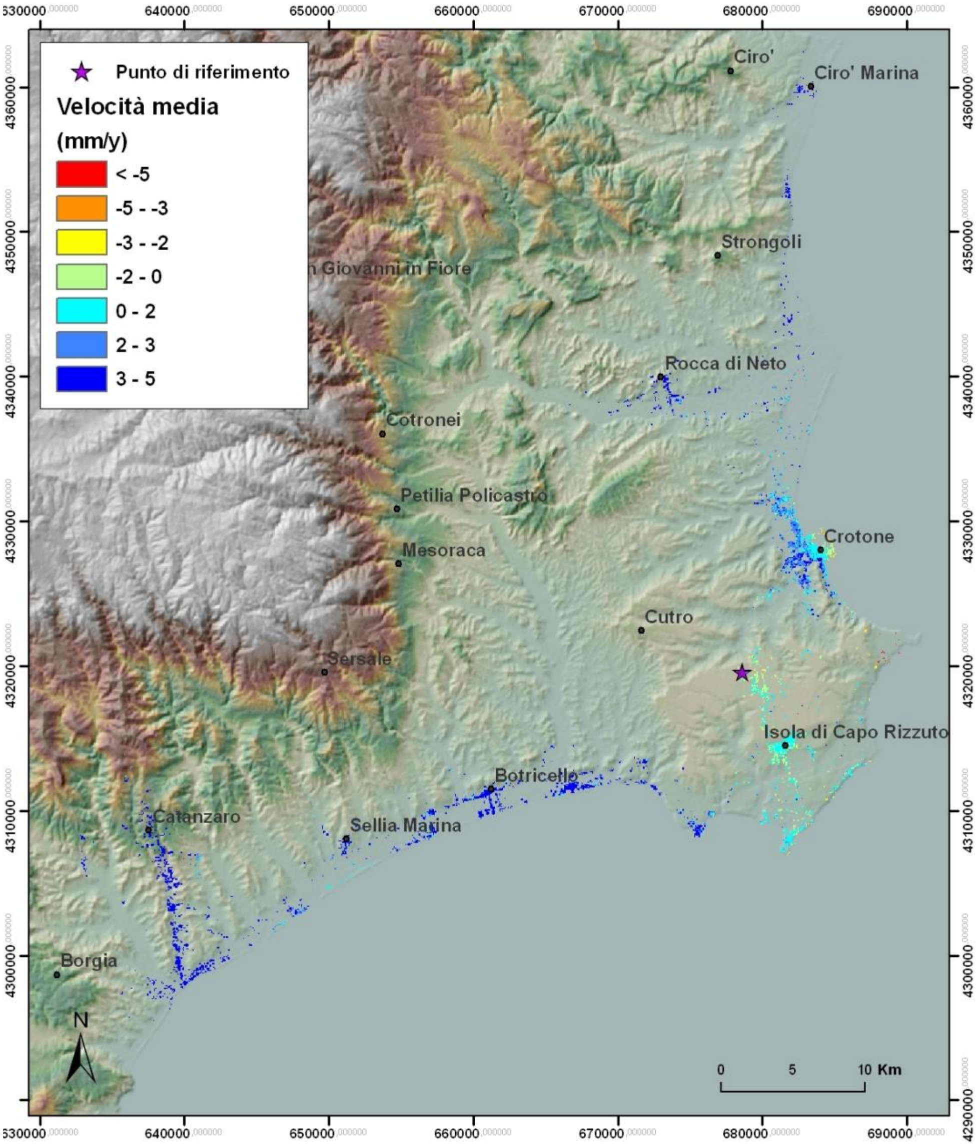

Figure 16: LOS velocity map along ascending path. The reference point is nearby Isola di Capo Rizzuto village.

Lab code	Locality ID	Locality	Lat	Lon	Marker elevation (m)	Error (±m)	Age (ky)	Error (±ky)	Cal Age BP 2sigma	Description
Poz-31064	130-131	Capo Colonna	39.029	17.205	6.74	0.25	29.120	0.26	-	Algal concretion with fragments of corals and bivalves.
Poz-31063	130-131	Capo Colonna	39.029	17.205	6.74	0.25	31.340	0.34	-	Bivalve shell of KR202A.
Poz-31067	101	Campolongo	38.930	16.997	1.92	0.50	42.300	1.20	-	Lithophaga shell in a boulder on a sandy beach.
Poz-31066	126	Chiacolilli	38.932	17.137	1.43	0.20	2.560	0.03	2140-2317	Algal rim on a beachrock slab.
Poz-31068	128	Marinella	38.986	17.163	3.81	0.50	35.100	0.50	-	Bivalve shell in a raised beach.
Beta - 261643	103-111; 132	Bosco Soverito	38.918	17.057	1.02	0.50	4.880	0.040	5300-5040	Lithophaga shell found in living position.
Beta - 261644	103-111; 132	Bosco Soverito	38.918	17.057	1.18	0.20	3.760	0.040	3810-3590	Algal rim, also with serpulides.
Beta-279336	103-111; 132	Bosco Soverito	38.918	17.059	0.84	0.20	0.00	0.050	-	Lithophaga shell found in living position. Possible 18th, 19th, or 20th century.

Table 3: Summary of radiocarbon dated samples.

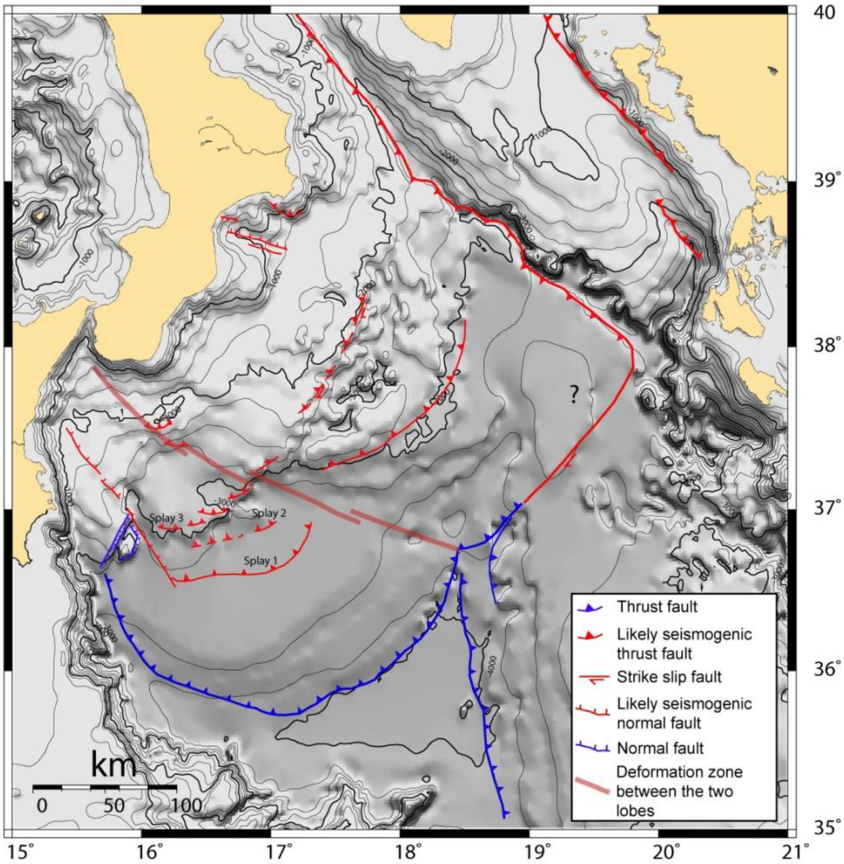

Figure 17: Structural map derived from the interpretation of the available seismic data. The outer deformation front and major structures are evidenced. The continental margin appears to be segmented both across and along strike. In particular, two lobes of the accretionary wedge are separated by a curvilinear structural boundary possibly accommodating different rates of shortening and slab dynamics.

Important results were obtained by RU 3.08 for the structure of the Ionian subduction, its accretionary prism and possible seismogenic character of the thrust faults within the accretionaty complex that were not mapped before this project (Figure 17). Results show the presence of two distinct accretionary prism bodies corresponding to the pre- and post-Messinian stages of the subduction with the basal detachment in the outer portion running along the base of the Messinian evaporites body with a shallow angle of 4°, whereas in the inner sector the basal detachment becomes steeper and deeper and seems to involve basement rocks. Within the accretionary body four active thrust faults (three belonging to the outer and one to the inner portion of the accretionary prism) that accommodate the plate motion were identified. This evidence confirms the present activity of the subduction, whose seismogenic behavior can be inferred based on modeled earthquake rates (RU T.01).

Maximum Observable Shaking

To evaluate the potential impact of expected earthquakes, RU 3.13 determined the Maximum Observable Shaking (MOS), and the near-field/far-field boundaries (NF/FF) with respect of the major seismogenic faults.

A set of MOS maps for the entire Italian territory was produced in the high-frequency domain (Figure 18), and expressed in terms of PGA (cm/s^2), PGV (cm/s), SI-HI (cm) and SD (cm) Several tests against independent data and sensitivity tests at local and national scale support the feasibility of the results.

A working framework about how potentially derive empirical relations that may allow delineating NF/FF boundaries was designed. With such a boundary, one can choose to simulate ground-shaking for a given type of building or infrastructure, according to whether its location occurs in the NF or FF regime, with respect to a given source, and for a given frequency of interest.

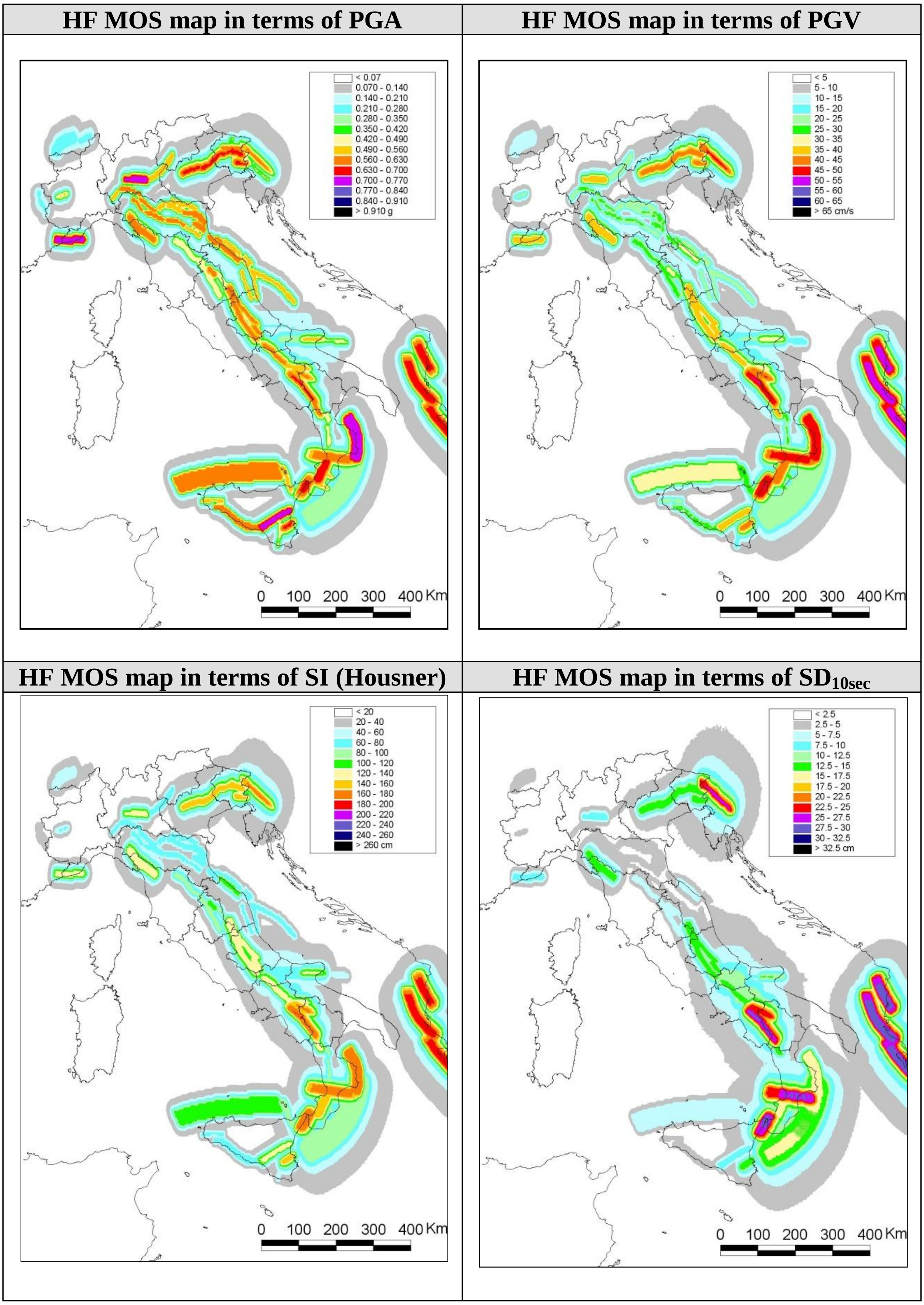

Figure 18: HF MOS maps in terms of PGA (g), PGV (cm/sec), SI-HI (cm) and SD10sec (cm) using the Gaussian slip distribution.

Tsunamis

The available records from historical catalogues and new contemporary sources have been collected on the 1832, 1836, 1905 and 1907 Calabria tsunamis (RUs 6.01-6.02-6.03 and 6.05; Figure 19). Information available on the 1169, 1693, 1783 and 1908 events has been also upgraded. All the historical data have been stored in the tsunami georeferenced database.

As for the Tsunami deposits along the coast of eastern Sicily, Task D researchers found evidence for the well-known 1908 tsunami probably only at Anguillara and Porto Palo sites and possibly at Morghella site too. The tsunami deposit associated with the 1783 event was identified only at the Capo Peloro site, confirming historical information that confines the effects of this tsunami to the northern part of the Messina Strait. RU researchers found the deposit of the 1693 tsunami at Priolo site (RU 6.02) and probably also in Pantano Morghella, Gurna and Anguillara sites (RU 6.01), where also an anomalous layer probably associated with the 1542 tsunami was identified. At Gurna, a tsunami deposit most likely related to the 1169 inundation was also found. Moreover, at Gurna, Priolo and Morghella sites records of inundation occurred in the time interval 100–600 A.D. and 220–600 A.D. could be related to the 365 A.D. tsunami. We collected interesting evidence of paleoinundations dated about 600–400 B.C. and 975–800 B.C. at Augusta, 800–600 B.C. at Priolo. Finally, evidence for a tsunami inundation occurred between 2300 and 1635 B.C. at Gurna and Priolo sites may be linked to the famous about 3600 BP Santorini event. The number of paleoevents found by this study confirms that tsunami recurrence time in eastern Sicily is about 300–400 years.

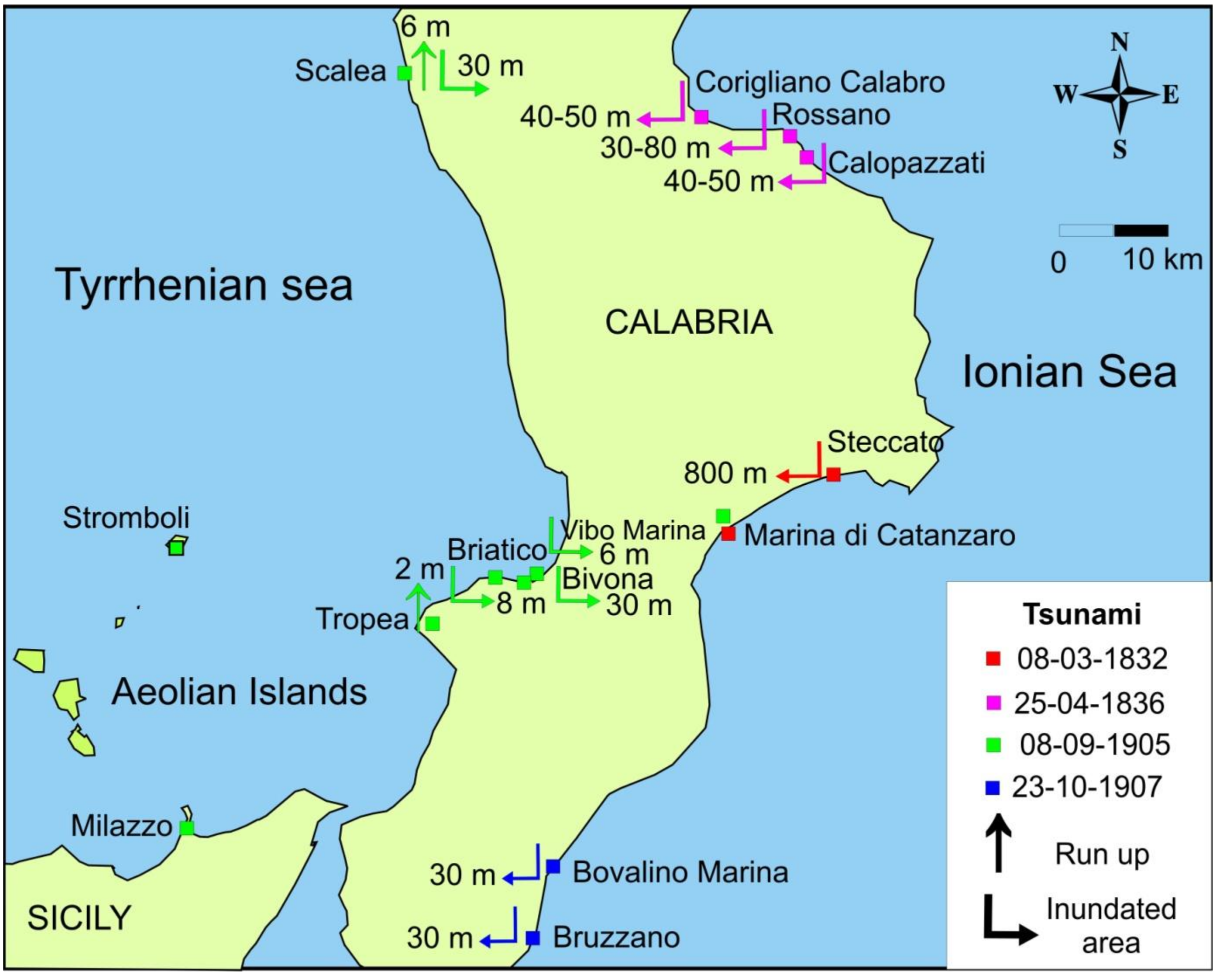

Figure 19: Locations affected by the minor Calabria tsunamis of 19th and 20th century.

Geodatabase

The project results have been organized into a database, where data files are available. The majority of results are expressed in geographical coordinates with a definite projection and transformed in shape files. The data format is compatible with the Italian public administration guidelines, allowing the S1 results to be integrated with pre-existing and future datasets maintained by other sources, such as the ISPRA (Italian Geological Service) (see http://labgis.gm.ingv.it/progettoS1_07_09/).

Deliverables

The table below lists the main planned deliverables and their status at the end of the project. The full list of deliverables can be found in the Task reports (details in the reports from RUs).

RU	RU responsible	Deliv. #	Status %	DPC	Deliverable	Type
T.01	Barba S.	DT.01.1	100	Y	Georeferenced database of all project results	Report, Webgis, Database
		DT.01.2	100	Y	Time-independent nationwide earthquake rates derived from models and geological data	Datafile+Report
		DT.01.3	100	Y	Role of the brittle-ductile transition on the seismic cycle	Report
		DT.01.4	100	Y	Report about the inconsistencies among the different methodologies in term of earthquake rates	Report
T.02	D'Ambrogi C.	DT.02.1	100		3D representations of seismogenic sources from DISS database, for the entire Italian territory. Preliminary and final releases are expected.	Datafile+Report
		DT.02.2	100		3D geological models of priority test areas	Datafile+Report
		DT.02.4	100	Y	Files, in common GIS file format, exported from the produced 3D models and representations.	Datafile+Report
1.01	Braìtenberg C.	D1.01.1	100		Tide gauge sea level rates Italian coastline	Datafile
		D1.01.2	100		Satellite altimetry sea level rates	Datafile
		D1.01.3	100		Apparent tectonic rates	Datafile
1.02	Caporali A.	D1.02.2	100	Y	GMT files with strain rates and stress drop at the center of clusters of permanent GPS stations in Italy and surrounding areas	Datafile+Report
1.03	D'Agostino N.	D1.03.A2	100	Y	Values of the geodetic moment rate on a regular 0.05° grid	Datafile
		D1.03.B1	100	Y	Geodetic slip-rates of block boundaries	Datafile
1.04	Devoti R.	D1.04.1	100		GPS time series of the Italian area	Datafile
		D1.04.2	100		Reference frame of the italian area: coordinates, velocities, offsets of a selected subset of fiducial sites	Datafile
		D1.04.3	100		Preliminary deformation field	Datafile
		D1.04.4	100	Y	Final deformation field of the italian area: coordinates and velocities	Datafile+Report
2.01	Chiarabba C.	D2.01.2	80		Seismic catalogue for the Italian territory (CSI 2.0): earthquake locations with regional velocity models and magnitude	Datafile+Report; final version to be delivered in September 2010.
2.02	Di Stefano R.	D2.02.1	100		3D P-wave and S-wave regional velocity model for Italy	Datafile (S-wave on request)
		D2.02.2	100		Integrated model (regional model merged with the available very high definition local scale models)	Datafile
		D2.02.3	100	Y	Updated map of the Moho topography, for the central Mediterranean region	Datafile
		D2.02.4	100		Software package for 3D velocity model handling, and local best 1D extraction	On request
2.03	Neri G.	D2.03.2	100		Databases of hypocenter parameters of the crustal seismicity occurring in eastern Calabria and western Sicily during 1981-2007	Datafile+Report
		D2.03.3	100		Detailed investigations of the most significant seismic phases and/or of the main clusters of seismicity in eastern Calabria and western Sicily, as contributions to the parametrization of the seismogenic structures	Report
2.04	Romanelli F.	D2.04.1	100		Database (suitable for GIS) containing the structural models vs. depth (~350 km) and uncertainties, for 1°x1° cells covering the Italian region	Datafile+Report
		D2.04.3	100	Y	Relocation, source mechanisms and seismic moment (table format) for earthquakes with Mw≥4.8 in the Italian region	Datafile+Report
2.05	Vannucci G.	D2.05.1	100		New release of Boxer code including a user-friendly interface	Report; software delivered in beta test, available on request.
		D2.05.2	100		New upgraded version of EMMA database	Datafile+Report
3.01	Basili R.	D3.01.1	100	pp	Technical report illustrating the results obtained in the Crotone Peninsula based on geological and InSAR data. Geological: map of coastal and fluvial terraces; map of long-term (100 ky) vertical movements. InSAR: ground velocity maps measured along both ascending and descending satellite orbits; vertical component of the ground velocity; East-West ground velocity map.	Report

RU	RU responsible	Deliv. #	Status %	DPC	Deliverable	Type
		D3.01.2	100	Y	Slip rate data on seismogenic sources included in DISS	Datafile+Report
		D3.01.3	100	N	Parameters of seismogenic sources in the key areas studied by RU 3.01 (contributing to populate DISS)	Datafile+Report
		D3.01.4	100	Y	Probability of occurrence for earthquakes generated by individual faults and the associated uncertainties	Datafile+Report
		D3.01.5	100	N	Results of tectonic validation for the seismogenic source model (DISS).	Datafile+Report
3.02	Catalano S.	D3.02.1	100	Y	1:25.000 scale morphotectonic map of the NE Sicily, from Capo Calavà to Milazzo and the 1:10.000 scale morphotectonic maps of Lipari and the eastern coast of Salina	Datafile+Report
3.02	Catalano S.	D3.02.4	100		Tables on the elevation and inferred age of the Late Quaternary marine terraces	Datafile+Report
3.04	Ferranti L.	D3.04.3	100	Y	Parameters of active structures (sea-land) for selected sectors of Sicily/Calabria	Datafile+Report
		D3.04.5	100	Y	Holocene vertical crustal displacement rates for selected sectors of Sicily/Calabria (final)	Datafile+Report
3.05	Galadini F. – Scardia G.	D3.05.1	100	Y	Evaluation of the Quaternary tectonic activity in the area between the Adda River and the Berici-Euganei axis	Report
3.06	Mariucci M.T.	D3.06.1	100	Y	Table with breakout analysis results	Datafile+Report
3.07	Michetti A.M.	D3.07.1	100	Y	Log of the excavated walls at the Monte Netto site, Brescia (Lombardia) in a scale of detail (up to 1:20) including AMS and OSL dating. (delivered in 1st year)	Delivered in 1st year
		D3.07.2	100	Y	Structural interpretation of the Monte Netto anticline and relationships with the causative backthrust. Assessments of the Late Quaternary slip rate of the Monte Netto anticline and modeling of the basal backthrust. (delivered in 1st year)	Delivered in 1st year
		D3.07.3	100	Y	GPR survey and geoelectric tomography in the Monte Netto area. (delivered in 1st year)	Delivered in 1st year
		D3.07.4	100	Y	High resolution, shallow seismic reflection profiles in the Lake garda offshore	Datafile+Report
		D3.07.7	100	Y	Regional mapping of the active compressional structures identified and assessment of the source parameters for seismic hazard assessment. (delivered in 1st year)	Delivered in 1st year
		D3.07.10	100	Y	Geomorphic investigation, field mapping and ENI seismic reflection data modeling along other Quaternary structure in the Lombardia Southern Alps (not planned)	Datafile+Report
3.08	Argnani A.	D3.08.2	100	Y	Characterization of the active tectonic structures of the peri-Gargano region and their relationship with sesmicity. (within report)	Report
3.08	Trincardi F.	D3.08.4	100		3D bathy-morphological reconstruction of the apulian slope and definition of the deformation pattern at the sea floor along Gondola fault (within report and geodatabase)	Datafile+Report
		D3.08.5	100	Y	Precise dating of the sedimentare units affected by the various segments of Gondola deformation belt; (within report and geodatabase)	Datafile+Report
3.08	Polonia A.	D3.08.7	100	Y	Line drawing of pre stack depth migrated seismic line CROP M-2B (within report)	Report
		D3.08.8	100	Y	Line drawing of Sparker seismic line J-08 (within report)	Report
		D3.08.9	100		Structural map of the Calabrian Arc in the Ionian Sea (within report and geodatabase)	Datafile+Report
3.09	Pucci S.	D3.09.3	100	Y	Structural maps of the key areas (scale 1:10.000 or 1:5.000) (western Sicily)	Datafile+Report
		D3.09.4	100		Geo-structural and morphological profiles of the key areas (scale 1:10.000 or 1:5.000) (western Sicily)	Datafile+Report
		D3.09.8	100	Y	Graphs of rates and values of the deformation and its distribution (western Sicily)	Datafile+Report
3.10	Scrocca D.	D3.10.1	100		Geometry of the basal detachment surface of the Northern Apennines accretionary prism beneath the Po Plain	Datafile+Report
		D3.10.2	100	Y	Improved definition of the geometry at depth of the "ITSA050 - Poggio Rusco-Migliarino", "ITSA051 - Novi-Poggio Renatico", "ITGG107 – Mirandola" sources	Datafile+Report
		D3.10.4	100	Y	Main geometric parameters for the "ITSA054 - Southern Marche offshore" and "ITSA052 - Mid-Adriatic offshore" sources	Datafile+Report
		D3.10.5	100	Y	Characterization of the seismogenic area "ITSA020 - Southern Marche"	Datafile+Report
3.11	Seno S.	D3.11.1	100	Y	Geological cross sections through the Po Plain (georeferenced and in a format suitable for importing in common GIS and database programs)	Datafile+Report
		D3.11.2	100	Y	Geometries and depth of fault planes and decollement levels (in 2 geological cross sections trough the Po Plain)	Report
3.12	Vannoli P.	D3.12.1	100	Y	A new version of DISS cointaining the scientific and technological updates stemming from the Project	Report+Datafile+Web+Google Earth. Final update in September 2010

RU	RU responsible	Deliv. #	Status %	DPC	Deliverable	Type
3.13	Zonno G.	D3.13.1	100	Y	Maximum Observable Shaking (MOS) maps of Italy in terms of PGA (cm/sec2) and SI-Housner (cm) but also in PGV (cm/sec) and SD (cm)	Datafile+Report
		D3.13.2	100	Y	Delimitation of Near-fields boundaries	Datafile+Report
		D3.13.3	100	Y	High-Frequency Maximum Observable Shaking Map of Italy from Fault Sources	Datafile+Report
3.14	Solarino S.	D3.14.3	100		1-D and 3-D tomographic models of Ligurian Sea	Datafile+Report
4.01	Lavecchia G.	D4.01.1	100		Source parameters on the likely seismogenic sources of the the Maiella and Abruzzi foothill earthquakes of 1706, 1881, 1882, 1933, 1950	Datafile+Report
4.02	Palombo B.	D4.02.1	80		Tables of seismic parameters (location, magnitude, focal mechanisms, seismic and geodetic deformation rates) for the earthquakes found in the Adriatic coast area, in the Calabrian area, and in the Central Latium (1919 Anzio earthquake)	Table+Report
5.01	Aoudia A.	D5.01.1	100		Short term (decadal) slip rate of the Castrovillari fault	Datafile+Report
5.02	Crescentini L.	D5.02.1	100		Technical Report on the blind inversions of synthetic coseismic deformation data (Apenninic environment)	Report
5.03	Megna A.	D5.03.1	100	Y	Analysis of heat flow in 5 areas	Datafile+Report
		D5.03.4	100	Y	Model-predicted strain rate map	Datafile+Report
		D5.03.5	100	Y	Model-predicted slip rate and fault kinematics	Datafile+Report
S.01	Gasperini P.	DS.01.1	90		Homogenized instrumental catalog from 1980 to present (and possibly extended to the entire XX century).	Datafile+Report
		DS.01.2	80		Completeness threshold of instrumental and historical catalog for different time intervals.	Report
		DS.01.4	70		Computing code for the estimate of the probability of occurrence of aftershocks in near real-time.	Report; code available on request
S.02	Rotondi R.	DS.02.1; DS.02.2	100		Occurrence probability in the tectonic regions MR and some seismogenic areas SA according to the seismic slip and the stress release models under different assumptions	Table+Report
		DS.02.3	100		Estimation of the probability density function of the recurrence time and approximation of the occurrence probability at different forecasting horizons for seismogenic areas according to renewal process	Table+Report
		DS.02.4	100		Simulation of the time of the next event with credible intervals according to the stress release model in the tectonic regions MR and some seismogenic areas SA	Table+Report
		DS.02.5	100		Occurrence probability for the Poisson model in the tectonic regions MR and some seismogenic areas SA	Table+Report
S.03	Slejko D.	DS.03.1	100		Form for the seismogenic sources with Mmax/Mchar, occurrence probability with confidences	Table+Report
S.04	De Rubeis V.	DS.04.1	100		Report on space-time clustering behavior of seismicity of Italian Region and definition of correlation and clustering ranges	Report
		DS.04.3	100		Report on macroseismic anomalous attenuation zones of Italian Region	Report
6.01; 6.02; 6.03; 6.05	Barbano M.S.; De Martini P.M.; Mastronuzzi G.; Tinti S.	D6.01.1; D6.02.1; D6.03.1; D6.05.1;	100		Upgrading the Catalogo degli Tsunami Italiani (Tinti et al., 2007)	Datafile+Report
6.01; 6.02; 6.03	Barbano M.S.; De Martini P.M.; Mastronuzzi G.	D6.01.2; D6.02.2; D6.03.2	100		Tables: maximum run-up, maximum inundation distance, tsunami recurrence (Sicily-Calabria).	Table+Report
6.01; 6.02; 6.03	Barbano M.S.; De Martini P.M.; Mastronuzzi G.	D6.01.4; D6.02.4; D6.03.4	100		Paleo-tsunamis (Sicily-Calabria) tables	Table+Report
6.04	Piatanesi A.	D6.04.1	100		Source mechanism of the 1908 Messina and 1905 Calabria earthquakes	Table+Report

Problems and difficulties

Main problems encountered are:

- Some of the RUs faced difficulties related with the precarious nature of research contracts held by many of the most active scientists;
- In few cases, having set mark too high;
- In two cases, lack of experimental design, especially in setting the appropriate geochronological framework;

- The experimental nature of the geodatabase has slowed down the data collection (due to repeated misunderstanding with some RUs who were already late in the timeline) and produced some mistake (some data have not been represented in their optimal form; whereas some data have been acquired but not integrated with the others). However, the problems are minor and an updated release of the database will be ready by September 2010 – this release will include all data, also those which were planned to be elaborated at the very end of the project.

Conclusions, perspectives and open issues

The S1 project computed the "predicted" earthquake rates for the Italian territory and surrounding regions based on different, independent geological and geophysical methods and datasets. All the methods were uniformed to produce moment rates in output, and all of the datasets were updated at the highest level possible and were organized in 2D and 3D databases. This procedure allows repeating and reproducing the results and allows implementing future updates in the data and the methods.

The comparison of the moment- and earthquake-rates indicates that:

1) In most of the Italian regions, the moment-rates are successfully predicted within reasonable uncertainty (~50%); as a consequence, the use of independent approaches allows reducing the stochastic uncertainties.
2) In a few Italian zones (see deliverable DT.01.2) very large differences (up to 10x) cannot be neglected; all such areas require further investigation. In certain cases, like the Ionian Sea, in-depth analysis of the different alternatives indicates that the historical seismic catalogue is largely incomplete, due to the limited time span, and the seismic potential is much larger than what was previously assumed.
3) Deriving earthquake rates is too much sensitive to the b-values. Although we used b-values taken from ZS9 seismic zonation, and although those b-values are consistent with the CPTI04 catalog, our feeling is that b-values and M_{max} derived on larger zones have to be used in order to derive earthquake rates from geodesy, finite element modeling and geology. Testing different zone dimension from small to large (respectively, ZS9, macroregions, and all Italy) makes us feel confident that intermediate to large regions have to be used, whereas the use of the ZS9 makes the predictions too sensitive on the duration of the seismic catalog.
4) The areas of Sulmona (Abruzzo), Ferrara arc, and Veneto Sud-Alpino appear to be geodetically locked at the best of our knowledge, where their long-term activity is widely accepted; although we cannot exclude other areas being locked as well, those three areas require further investigation.

The S1 project focused its scientific goals on the structural and geodynamic setting governing the seismogenic sources of the Italian territory. A number of fundamental issues were neglected, assuming they would be further priorities to be tackled in future plans. These are specifically:

1) A geochemical and hydrologic monitoring along active faults in Italy. This project should be organized for a long term data acquisition, possibly in cooperation with ARPA agencies in the different regions.
2) New acquisition of seismic reflection profiles along active faults or areas where the structural information is scarce, and crucial for the understanding of the Italian tectonics. Few examples could be cross sections of Calabria, the Tiber valley, the Apulian escarpment, the Messina Strait, etc.
3) The completeness of the rheology computation of the Italian lithosphere, only preliminarily faced in S1.

These main topics should be accompanied by a continuous updating of the activities touched by S1, such as:

- the permanent collection of field data along active faults;

- the improvement on the resolution of the crustal and lithospheric structure;
- the integration of geological data with GPS velocity field;
- the analysis and the relationship between strain-rate and most earthquake-prone areas;
- numerical modeling of the deformation and geodynamics of Italy;
- the permanent on-going growth of the 3D or 4D data base, including all information (seismic catalogue, geology, geophysics, geochemistry, space geodesy, etc.), and available to the whole scientific community.

Main key publications

Argnani A., Rovere M. and Bonazzi C., 2009. Tectonics of the Mattinata Fault offshore south Gargano (southern Adriatic Sea, Italy): implications on active deformation in the foreland of the Southern Apennines. G.S.A. Bull., 121: 1421-1440.

Argnani, A., Chiocci, F.L., Tinti, S., Bosman, A., Lodi, M.V., Pagnoni, G., Zaniboni F., 2009. Comment on "On the cause of the 1908 Messina tsunami, southern Italy" by Andrea Billi et al. Geophys. Res. Lett. 36, 13, doi:10.1029/2009GL037332.

Avallone A., Selvaggi G., D'Anastasio E., D'Agostino N., Pietrantonio G., Riguzzi F., Serpelloni E., Anzidei M., Casula G., Cecere G., D'Ambrosio C., De Martino P., Devoti R., Falco L., Mattia M., Rossi M., Obrizzo F., Tammaro U., Zarrilli L., 2010. The RING network: improvement of a GPS velocity field in the central Mediterranean. Annals of Geophysics, 53 (2).

Barba, S., Basili, R., Carafa, M.M.C., Balestra, F., 2008. Depth of the seismogenic layer in Italy, AGU Fall Meeting, 15-19 December 2008, San Francisco, California.

Barba, S., Carafa, M.M.C., Mariucci, M.T., Montone, P., Pierdominici, S., 2008. Active stress field modelling in the southern Apennines (Italy) using new borehole data. Submitted to Tectonophysics.

Barbano, M.S., Pirrotta, C., Gerardi, F., 2010. Large boulders along the south-eastern Ionian coast of Sicily: storm or tsunami deposits? Marine Geology, in press. DOI: 10.1016/j.margeo.2010.05.005.

Basili, R., Kastelic, V., Valensise, G., DISS Working Group, 2009. DISS3 tutorial series: Guidelines for compiling records of the Database of Individual Seismogenic Sources, version 3. Rapporti Tecnici INGV, 108: 20 p. http://portale.ingv.it/produzione-scientifica/rapporti-tecnici-ingv/archivio/rapporti-tecnici-2009/

Braitenberg C., Mariani P., Tunini L., Grillo B. Nagy I., 2009. Vertical crustal movements from differential tide gauge observations with the control from satellite altimetry. Submitted to Journal of Geophysical Research.

Brandmayr, E., Raykova, R., Zuri, M., Romanelli, F., Doglioni, C., Panza, G., 2010. The lithosphere in Italy: structure and seismicity. In: (Eds.) Marco Beltrando, Angelo Peccerillo, Massimo Mattei, Sandro Conticelli, and Carlo Doglioni, Journal of the Virtual Explorer, volume 36, paper 1, doi: 10.3809/jvirtex.2009.00224.

Caporali, A., Barba S., Carafa, M.M.C., Devoti, R., Pietrantonio, G., Riguzzi, F., 2010. Static stress drop as determined from geodetic strain rates and statistical seismicity. Submitted to Journal of Geophysical Research, April 2010.

Carminati, E., Scrocca, D., Doglioni, C., 2010. Compaction-induced stress variations with depth in an active anticline: Northern Apennines, Italy. Journal of Geophysical Research, 115, B02401, DOI:10.1029/2009JB006395.

Cuffaro, M., Riguzzi, F., Scrocca, D., Antonioli, F., Carminati, E., Livani, M., Carlo Doglioni, 2010. On the geodynamics of the northern Adriatic plate, Rendiconti Accademia Lincei, (submitted).

De Martini, P.M., Barbano, M.S., Smedile, A., Gerardi, F., Pantosti, D., Del Carlo, P., Pirrotta, C., 2010. A unique 4000 yrs long geological record of multiple tsunami inundations in the Augusta Bay (eastern Sicily, Italy). Submitted to Marine Geology.

de Nardis, R. and Lavecchia, G., Search-grid inversion-based investigation for the seismogenic sources of historical earthquakes: the Maiella 1706 (Mw 6.8) case study, Central ITALY, to be submitted to Bulletin of the Seismological Society of America

Dessa, J.X., Simon, S., Lelièvre, M.., Beslier, M.O., Deschamps, A., Béthoux, N., Solarino, S., Sage, F., Eva, E., Ferretti, G., Bellier, O., Eva, C., 2010. The GROSMarin Experiment: Three Dimensional Crustal Structure of the North Ligurian Margin From Refraction Tomography and Preliminary Analysis of Microseismic Measurements. Bulletin de la Societe Geologique de France, submitted.

Devoti R., Pietrantonio G., Pisani A. R., Riguzzi F. and Serpelloni E. 2010. Present day kinematics of Italy. In: (Eds.) Marco Beltrando, Angelo Peccerillo, Massimo Mattei, Sandro Conticelli, and Carlo Doglioni, The Geology of Italy, Journal of the Virtual Explorer, Electronic Edition, ISSN 1441-8142, volume 36, paper 2.

Di Bucci, D., Burrato, P., Vannoli, P., Fracassi, U., Valensise, G., submitted. Seismogenic faults and their surface signature: insights from the 2009 L'Aquila earthquake (Central Apennines, Mw 6.3) for the understanding of adjacent areas. Terra Nova.

Di Bucci, D., Ridente, D., Fracassi, U., Trincardi, F., Valensise G., 2009. Marine paleoseismology from Very High Resolution seismic imaging: the Gondola Fault Zone (Adriatic foreland). Terra Nova, 21: 393-400.

Di Bucci, D., Ridente, D., Fracassi, U., Trincardi, F., Valensise, G., 2010. Marine paleoseismology from Very High Resolution seismic imaging: the Gondola Fault Zone (Adriatic foreland). Terra Nova, 21: 393-400. doi: 10.1111/j.1365-3121.2009.00895.x.

Di Stefano, R., Castello, B., Chiarabba, C., Ciaccio. M.G., 2010. A detailed three-dimensional P-wave velocity structure in Italy from local earthquake tomography. Geophys. Res. Abstracts,12, EGU2010-14718, 2010, EGU General Assembly 2010.

Ferranti, L, Antonioli, F., Anzidei, M., Monaco, C., Stocchi, P. - The timescale and spatial extent of vertical tectonic motions in Italy: insights from relative sea-level changes studies. Journal of the Virtual Explorer, Special Issue: The Geology of Italy, in press.

Ferranti, L., Mazzella, M. E., Monaco, C., Morelli, D., Santoro, E., 2009. Active transpression within the frontal zone of the Southern Apennines in northern Calabria by integration of geomorphologic, structural, and marine geophysical data. Rend. online Soc. Geol. It., 5, 97-99.

Ferranti, L., Santoro, E. Mazzella, E., Monaco, C., Morelli, D., 2009. Active transpression in the northern Calabria Apennines, Southern Italy. Tectonophysics, 476: 226–251 doi:10.1016/j.tecto.2008.11.010.

Gasperini P. and Lolli B. (2009) An empirical comparison among aftershock decay models, Phys. Earth Plan. Int. doi:10.1016/j.pepi.2009.03.011.

Gasperini P., Vannucci G., Tripone D. and E. Boschi, 2010. The location and sizing of historical earthquakes using the attenuation of macroseismic intensity with distance, Bull. Seism. Soc. Am., in press

Gasperini P., Vannucci G., Tripone D., 2009. A new version of "Boxer" code for the determination of seismic source parameters from macroseismic data. Abstract presented at the EGU 2009 Conference, Wien (Austrian), 2009 April 20-24.

Gerardi, F., Barbano, M.S., De Martini P.M., Pantosti D., 2008. Discrimination of the nature of tsunami sources (earthquake vs. landslide) on the basis of historical data in eastern Sicily and southern Calabria. Bull. Seism. Soc. Am., 98 (6): 2795–2805.

Guarnieri, P., Pirrotta, C., Barbano, M.S., De Martini, P. M., Pantosti, D., Gerardi, F., Smedile, A., 2009. Paleoseismic investigation of historical liquefaction along the Ionian coasts of Sicily. Journal of Earthquake Engineering, 13, 68–79, DOI: 10.1080/13632460802212030.

Livio F.A., Berlusconi A., Michetti A.M., Sileo G., Zerboni A., Trombino L., Cremaschi M., Mueller K., Vittori E., Carcano C., Rogledi S., 2009. Active fault-related folding in the epicentral area of the December 25, 1222 (Io = IX MCS) Brescia earthquake (Northern Italy): seismotectonic implications. Tectonophysics – Vol. 476, Issues 1-2, pp. 320-335.

Lolli B., Boschi E. and Gasperini P. (2009). A comparative analysis of different models of aftershock rate decay by maximum likelihood estimation of simulated sequences, J. Geophys. Res., 114, B01305, doi:10.1029/2008JB005614.

Lolli B., Gasperini P. and Boschi E., (2010) Time variations of aftershock decay parameters of the April 6, 2009 L'Aquila (Central Italy) earthquake: evidence of the emergence of a negative exponential regime superimposed to the power-law, Geophys. J. Int. (under revision).

Neri, G., Orecchio, B., Presti, D., Totaro, C. 2010. Defining a new 3-D lithospheric velocity model of the Calabrian Arc region (Southern Italy) from the integration of different seismological data. In: Geophysical Research Abstracts Vol 12, EGU General Assembly 2010 Vienna, 02-07 Maggio.

Olivetti, V., M. L. Balestrieri, C. Faccenna, F. M. Stuart, and G. Vignaroli (2010), MiddleMiocene out-of-sequence thrusting and successive exhumation in the Peloritani Mountains, Sicily: Late stage evolution of an orogen unraveled by apatite fission track and (U-Th)/He thermochronometry,Tectonics, doi:10.1029/2009TC002659, in press.

Sbarra P., Tosi P and De Rubeis V. 2009. Web based macroseismic survey in Italy: method validation and results. Natural Hazard DOI: 10.1007/s11069-009-9488-7.

Pino, N.A., A. Piatanesi, G. Valensise and E. Boschi (2009): The 28 December 1908 Messina Straits earthquake (Mw 7.1): a great earthquake throughout a century of seismology, Seismol. Res. Lett., 80(2), 243-259, doi: 10.1785/gssrl.80.2.243.

Polonia A., Torelli L., Gasperini L., Riminucci F., Mussoni P., Gallais F., Gutscher M.-A., Artoni A., and Klaeschen D. The Calabrian Arc subduction complex in the Ionian sea: regional architecture, active deformation and seismic hazard. Submitted to Tectonics.

Sabadini, R., Aoudia, A., Barzaghi, R., Crippa, B., Marotta, A.M., Borghi, A., Cannizzaro, L., Calcagni, L., Dalla Via, G., Rossi, G., Splendore, R., Crosetto, M, 2009. First evidences of fast creeping on a long-lasting quiescent earthquake normal-fault in the Mediterranean, Geophysical Journal International, Volume 179, 2, 720-732.

Sciunnach, D., Scardia, G., Tremolada, F., Premoli Silva, I., in press. The Monte Orfano Conglomerate revisited: stratigraphic constraints on Cenozoic uplift of the Southern Alps (Lombardy, Northern Italy). International Journal of Earth Science, DOI 10.1007/s00531-009-0452-2, on-line 29 May 2009.

Slejko, D., Caporali A., Stirling, M. Barba, S., 2010. Occurrence probability of moderate to large earthquakes in Italy based on new geophysical methods. J. Seismol., 14: 27-51, DOI 10.1007/s10950-009-9175-x.

Tinti, S., Gallazzi, S., Armigliato, A., Tonini, R., Pagnoni, G., Manucci, A., 2010. Updating of the Italian Tsunami Catalogue for southern Italy with special emphasis on the reconstruction of the 1908 Messina Straits tsunami effects. Abstract and poster presented at the EGU General Assembly 2010, Vienna (Austria), May 2-7 2010 (also in Geophysical Research Abstracts, Vol. 12, EGU2010-6680).

Toscani, G., Burrato, P., Di Bucci, D., Ahmad, I., Seno, S., Valensise, G. 2010. Active thrusting underneath the Po Plain (Bologna-Ferrara section, Italy): insights from analogue modeling. Submitted to Terranova

Toscani, G., Burrato, P., Di Bucci, D., Seno, S. & Valensise, G. 2009. Plio-Quaternary tectonic evolution of the Northern Apennine thrust front (Bologna-Ferrara section, Italy): seismotectonic implications. Italian Journal of Geosciences, vol. 128 n°2, 605-613. doi 10.3301/IJG.2009.128.2.605

Zuri, M., 2009. Proprietà meccaniche cellulari della litosfera della regione italica, Tesi di Laurea in Scienze Geologiche, Università degli Studi di Trieste.

Section 2: Report on the project by Task leaders

Task A: Earthquake Geodesy and Modeling

Task information

Task A Earthquake geodesy and modelling
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Progress of the task: general

The activities comprising Task A that have different goals and use different data. As a result, the various activities are only weakly connected one to the other. This circumstance has prevented the delays of some RUs from affecting the rest of the group. In fact, some of the RUs have fulfilled their initial commitments from the end of the first year, while others picked up only in the second year. At any rate, all activities of Task A have been completed. Some have returned successful results and updates that will certainly have an impact on subsequent research efforts, whereas others have tackled more elusive problems and produced very specific results that may not be of wide relevance for the goals of the project. The occurrence of the 6 April 2009, L'Aquila earthquake (Mw 6.3) delayed the work of some RUs but also provided a most interesting and "living" test case for some of the activities.

Progress of the task by RUs

The following section summarizes the final results achieved by each RU in the frame of the activities gathered under Task A.

RU 1.01 (Braitenberg) completed all planned activities. The RU analyzed data from 26 mareographic sites along the 7,570 km-long Italian coastline, determined sea level variatuions at each site and calculated apparent tectonic rates at 12 tide gauge stations all over the peninsula. The work relied on satellite altimetric measurements supplied by the Topex-Poseidon and Jason-1 missions and on two mareographic databases, respectively operated by ISPRA and PSMSL. All the input data are publicly available. Retrieved sea level trends vary in space as well as in time. The rates are rather scattered due to the combined effect of crustal movement rates, varying eustatic rates, and variations in the time intervals used for determing the rates. Trend values obtained over a time interval shorter than 30 years are representative of a certain time interval and can be very different from the average secular trend. Results from the first year showed a consistent linear sea level increase trend for the interval 1998.6 al 2007.9 for most tide gauge stations, with notable exceptions at Reggio Calabria (few data available) and Messina (known instability of the instrumentation). Sea level rose along the Venetian-Trieste coastline, the Campania coast, Lampedusa and Sardinia. Also the Ligurian coast, much of the Tyrrhenian coast and the Ionian coast between Crotone and Taranto show positive sea level values. The northern Adriatic shows sea level fall, whereas the southern Adriatic exhibits sea level rise. In southern Sicily and in Calabria the sea level trends oscillate around zero, except for Porto Empedocle. Results for the second year extended the observation time window from 1998.6 to 2009.5. The data are rather scattered and fraught with uncertainties that are difficult to sort out, particularly in the determination of apparent tectonic uplift rates. Nevertheless, the results of this RU are certainly innovative and encouraging as they may complement vertical crustal movement rates obtained from GPS and from conventional repeated leveling techniques.

RU 1.02 (Caporali) focused on the determination of the velocity of permanent GPS stations and on the associated strain rates, largely in collaboration with RU 1.04. The analysis used state-of-the-art software (Bernese 5.0) and the IGS – EUREF recommended processing strategies. The results presented are based on processing of data up to May 2010. For maximum accuracy the UR used the EUREF scheme of processing daily data sets and then stacking the daily normal equations spanning one week to produce a weekly normal equation, yielding a total of 520 weekly normal equation files (1999 – May 2010). The analysis included several stations which are not part of the INGV RING network, particularly in Northern Italy.

The RU prepared several different elaborations, some of which were not originally planned. A map of the strain rate for the entire country has been constructed and discussed in the context of the CPTI04 Seismic Catalogue and to the 36 seismic zones of the seismic zonation ZS9 (Meletti et al., 2008). The RU calculated the static stress drop expected for each seismic zone of ZS9 under the asumption that all strain is released seismically. The resulting areas of largest stress drop are in NE Italy, in the Central Apennines and in the Gargano area. These are zones of different stress regime, suggesting that the distribution of the static stress drop is independent from the type of deformation (extension, compression or shear). It was remarked that the stress drop seems to correlate with the time elapsed since the last largest recorded earthquake in each seismic zone, an observation that could have a profound impact on fundamental aspects of seismic hazard but that needs to be confirmed by more precise estimates and statistics.

The RU also performed an analysis of GPS strains following the 6 April 2009 L'Aquila earthquake. The analysis aimed at deriving the main faulting parameters and the gross features of the coseismic slip distribution.

RU 1.03 (D'Agostino) analyzed and interpreted the GPS velocity field of the Italian territory using two independent approaches. In the first the crustal horizontal strain rate field was modeled under the assumption that the crust deforms as a continuum. In the second the region was subdivided into a number of fault-bounded blocks; each block is then characterized in terms of rotation rate and the sense and magnitude of slip on the bounding faults. Each approach has its own advantages and limitations, which are candidly discussed in the final report.

During the second year of the project the RU has operated along both approaches and has supplied interesting results summarized in a number of figures and deliverables. The strain rate modeling approach shows very consistent and stable results, at least for the Central and Southern Apennines where the station distribution and geometry are better than elsewhere in Italy. The results emphasize the existence of a 40-60 km-wide extensional belt coincident with the topographic culmination of the Apennines. This belt is undergoing deformation at rates up to 50-60 nstrain/y. A comparison of geodetic rates with strain rates derived from historical seismicity using Kostrov's equation shows a substantial similarity of these two estimates over the entire Central and Southern Apennines, suggesting that most of tectonic deformation is absorbed into earthquakes. This conclusion differs strongly from previous studies indicating a geodetic-seismic strain ratio much larger than 1, which called for the existence of a significant component of aseismic deformation along the Apennines belt.

The block modeling approach used Composite Sources from the DISS 3.1.0 database to infer slip rates for individual faults. Even when all uncertainties and limitations are takn into account, the results of the analysis are very interesting and show slip rates averaging about 1 mm/y for the entire Italian peninsula, in agreement with results from field studies and from geodynamic modeling.

The UR also developed an effective GIS interface to design the model input and to visualize model results.

The figures and the deliverables supplied demonstrate that most and possibly all of the work originally planned has been accomplished, although the GPS field operations following the l'Aquila earthquake of 6 April 2009 somehow delayed the performance of this research group.

RU 1.04 (Devoti) was in charge of reassessing the GPS velocity field of the entire Italian area. To this end the RU processed all the available permanent GPS observations in the interval

1998-2009 using two different softwares (Bernese v. 5.0 and Gamit-Track v. 10.33) and hence obtaining two independent velocity fields. The analyses are based on about 400 permanent GPS sites supplied by EUREF (International GNSS Service), RING (Istituto Nazionale di Geofisica e Vulcanologia), ASI (Agenzia Spaziale Italiana), FREDNET (Istituto Nazionale di Oceanografia e Geofisica Sperimentale), ITALPOS (Leica), Regione Puglia, Regione Friuli, Regione Lombardia, University of Perugia, University of Calabria (UNAVCO) and other universities and local authorities.

Estimates of the velocity field are especially robust as they take into account instrumental changes, annual sinusoids, sporadic offsets and outliers using a specifically developed and well-tested software.

The comparison of the horizontal velocity fields estimated from the two independent time series (Bernese and Gamit) shows differences in the order of 0.6 mm/yr in the horizontal plane and 0.7 mm/yr in the vertical components. A previous comparison between the the preliminary Bernese velocity solution supplied by the current UR and the velocity solution provided by the University of Padova (RU 1.02) returned differences in the order of 1 mm/yr, hence higher than the Gamit-Bernese agreement, showing that a close interaction between analysis centers is strongly needed to improve the quality of the results.

The combined solution in the Eurasia fixed reference frame shows clearly that the extensional belt running along the Apennines is the most significant tectonic feature of the entire Italian area. Typical values range between 20-60 nstrain yr^{-1} although with variable magnitude along the chain. Significant shortening associated with pure compressional dilatation is seen in the Dinaric Arc, in the eastern Alps and offshore north-west of Sicily.

The RU also developed an iterative method to estimate the velocity field of a GPS network by adding recursively the daily coordinates. The velocity field is obtained as the solution of the restricted least squares problem.

RU 2.02 (Di Stefano) produced a high resolution 3D velocity model of the lithosphere in Italy from regional to local scale by integrating information from seismic tomography, controlled source seismology and Receiver Functions. The improved resolution and detailedness of the new velocity models for the Italian region makes them suitable for use in routine seismological analysis. Both the quality of earthquake monitoring and the definition of earthquake source parameters definition will strongly benefit from this advancement.

The RU obtained two updated P-wave tomographic regional models by adding 299,924 P-wave arrival observations relative to 7,236 earthquakes recorded in the period 2003-2008 to the previously inverted dataset, which included 165,000 P-wave arrivals. The additional events have been selected from CSI 2.0 with strict quality criteria. Model 1 has a grid spacing of 15 km and is computed for the whole study region whereas Model 2, that is calculated on a finer grid (10 km) is defined only for selected areas.

The RU also computed a new map of the Moho topography as a key element for an integrated and improved 3D regional velocity model. The Moho map has been updated and stabilized by including new controlled source seismology data for the Western Tyrrhenian Sea, previously not covered by original data, and new data from a large number of Receiver Functions. A method developed by Waldhauser (1996) has been used to reduce the misfit between the data and the final interpolated surface using *a priori* information on the geodynamic setting of the study region. The Mediterranean region has been subdivided into 3 main polygons representing geodynamic provinces over which the interpolation was performed.

Using an interpolation with a cell size of 1 km the RU obtained an integrated 3D regional velocity model whose grain is hence comparable to that of the details of available small scale tomographies. The 3D model has been used to obtain 3D travel times following different approaches.

RU 2.04 (Romanelli) used surface wave tomography and non-linear inversion of dispersion curves to complete 1°x1° cell structural models for the whole Italian region. This effort is intended to extend the work done by Panza et al. (2007) for the Tyrrhenian Sea and surroundings. The RU used dispersion curves of Rayleigh fundamental modes along properly selected wave paths to obtain the S-wave velocities and the thickness of the layers by non-linear inversion. The available database is suitable to explore the S-wave velocity structure down to a depth of about 350 km. Available interpretations of the seismic profiles that cross most of the Alps and adjacent areas along with information from literature served as *a priori* information to fix the thickness h and the V_p of the uppermost crustal layers, assuming that they are formed by Poissonian solids.

The RU results may be summarized by five different categories of elaborations:
- structural models (mechanical properties vs. depth, ~350 km, with uncertainties) for 1°x1° cells for the whole Italian region; the total of the analyzed cells is 125, resulting in a geographical coverage that goes well beyond the initially expected limits.
- refinement of the models, with two other optimization methods that have been applied for the first time at such a scale;
- construction of databases for the entire study region, with the structural models in a format suitable to GIS;
- relocation and re-evaluation of the seismic moment tensor for all Mw≥4.8 Italian earthquakes and assessment of the associated stress field;
- definition of the lithospheric thickness and its mechanic properties according to the distribution of seismicity and the seismic source parameters.

RU 5.01 (Aoudia) had three fundamental goals: a) calculating the slip rate distribution over the long quiescent Castrovillari normal fault using the results of 5 GPS campaigns and InSAR elaborations; b) running the 6th GPS campaign over a network of 10 sites set up in 2003 around the long-quiescent Castrovillari normal fault, and computing the mean strain rate; and c) testing a methodology for investigating transient deformation in continuous GPS time series.

For the Castrovillari area the GPS velocity field shows significantly non zero velocities (at significance level $\alpha = 1\%$) and a different behaviour across the fault. GPS and InSAR data returned nearly coincident results in the northern part of the fault, where the InSAR observations are reliable enough.

Data from the 6th GPS campaign show that the estimated horizontal principal strain rate axes document extension perpendicular to the fault at rates that are one order of magnitude larger than those seen at the regional scale and at the scale of the central Mediterranean. The observed velocities are consistent with those reported for the area based on observations from the national GPS network.

The third application uses a modified Bayesian approach to identify potential transients within the CGPS time series and to investigate unknown time series discontinuities. During the second phase of the project this approach was applied to pre-6 April 2009 observations from the L'Aquila region. The RU first focused on the Cascadia subduction zone, where the same discontinuities in the signals recorded by a dense CGPS network have been retrieved using three different methods. After reduction of the data, the trend of the trace of the strain-rate tensor based on velocities computed over a 6-month interval shows a de-correlation with the monthly seismic moment of the L'Aquila area that began a few months before the mainshock.

RU 5.02 (Crescentini) improved the version of the already existing ANGELA code for the inversion of coseismic deformation data. In particular the code has now the capability to deal with listric faults, which are modeled as consisting of a shallower segment and a deeper one, both rectangular in shape and sharing an horizontal side. The optimal number of sub-faults is set based on the approach known as AIC (Akaike Information Criterion). In the uniform-slipping case and when each segment is divided into a small number of independently-slipping, equally-raking subfaults, all fault parameters are kept free.

ANGELA has been used to invert synthetic data generated by RU 5.03 using a 3D finite-element model and based on different 2D Apenninic crustal structures and fault slip distributions. The inversions were completely blind, apart from the *a priori* information that the fault used by UR 5.03 was rectangular in shape. ANGELA confirmed its capability to perform reliable inversions of geodetic co-seismic data for a large number of model parameters, using more realistic source and Earth models. As regards the blind inversions performed using three distinct 1D crustal structures (homogeneous half-space, layered models), the main results are:

- the fault geometry (size, location) and mechanism are always retrieved well; the misfit depends on layering, probably because of the absence of a thin soft superficial layer in the 2D forward model (see Figure 2); for the same reason, slip magnitude is underestimated;
- the AIC always selects the model (small number of equally-sized sub-faults) that gives the best approximation to the forward model;
- the AIC always selects the optimal number of sub-faults in the distributed-slip model.

RU 5.03 (Megna) continued and improved the research activities carried out by the RU 3.1 of project S2 of the 2004-2006 INGV-DPC agreement, that focused on numerical modelling of deformation processes at the regional scale. One of the goals of the RU was the study of strain partitioning at the scale of a single fault system. In such circumstances several "regional scale" assumptions (i.e. uniform fault friction or homogenous rheological properties) are insufficient to reproduce realistic conditions on structures at local scale. In such cases modelling local heterogeneities becomes fundamental. The RU carried out a local modelling for the rheological properties of the Northern Apennines, for the fault friction influence on the Mattinata fault system and for the variation of S_{Hmax} orientation in the Southern Apennines.

The RU initially gathered all the data needed to calculate the stress and strain regimes at national scale, including focal mechanisms taken from the EMMA database (Vannucci and Gasperini, 2003), stress data from S_{Hmax} measurements (from Mariucci et al. 2004 and Heidbach et al. 2008), GPS measurements from Devoti et al. (2008), heat flow data and geothermal gradient to estimate the strength of the lithosphere, crustal and lithospheric structure data obtained by other RUs of the project (2.02 and 2.04).

These input data were use to test and score the predictions of a dynamic model based on a code developed by Bird (1999) to predict velocities and stresses. Modeling follows the approach of Barba et al. (2008). The RU generated 970 "base models" for which the uncertainties of the analysed parameters are spread. The scoring datasets include the geodetic velocities, the azimuth of stress directions and the tectonic regime implied by fault plane solutions. The final average model shows lower misfits with respect to the final geodynamic model obtained in 2007 by the RU 3.1. In particular the best fitting model improves the misfit with respect to GPS measurements from 1.64 mm/a to 1.08 mm/a.

The RU also calculated slip rates and their standard deviations were calculated for faults located inside the stable area of the model. All faults falling in each Composite Seismogenic Source (CSS) of the DISS database (v. 3.1.0) (Basili et al., 2008) were also grouped and their slip rates were averaged to give the CSS's slip rate. The slip rates have been validated by comparing them with geological values (in collaboration with UR 3.12). Model slip rates fall in the same range as geological slip rates, and the moment rate due to slip-rate represents nearly 50% of the whole deformation rate of the model. Such pattern of slip rates seems to be realistic, indicating that the model and the geodetic-geological data can be successfully integrated to give an independent set of results. The remaining discrepancies are believed to depend on the approximation of the used code (for example in the Po Plain area), or occurr in areas for which DISS does not report any faults, such as Tuscany. The largest values are found for the Ionian arc (up to 3mm/y) and the Central Apennines (2mm/y).

The RU also calculated anelastic long-term horizontal velocities and their standard deviations within the stable area of the model. The average values of the horizontal velocities are in a good agreement with the GPS measurements dataset (average RMS = 1.08 mm/a). The associated strain rates represent long-tem anelastic strain rates as they are calculated on continuum elements of the model and do not consider the deformation released as slip rates on faults. Higher values of strain rates are obtained for the Tyrrhenian region and along the axis of the Apennines. The map of Sh_{max} exhibits an average misfit of 24° compared to the dataset of observed SH_{max}, considering only A and B quality measurements. Taking into account all the data (quality from A to D), for large parts of the Apennines, Sicily and the Dinarides the average misfit falls below 25°. Such findings confirm a good fit between the model and the observed data.

A further test concerned the determination of the frictional properties of the Mattinata fault in the Adriatic foreland. The 0.4-0.5 effective fault coefficient obtained is lower than normal values (0.6), implying that the Mattinata may represent a structural weakness which may focus the release of seismic energy.

Deliverables

The table below summarizes the planned deliverables and their status at the end of the project.

RU	RU responsible	Deliv. #	Status %	DPC	Deliverable
1.01	Braìtenberg C.	D1.01.1	100		Tide gauge sea level rates Italian coastline
1.01	Braìtenberg C.	D1.01.2	100		Satellite altimetry sea level rates
1.01	Braìtenberg C.	D1.01.3	100		Apparent tectonic rates
1.02	Caporali A.	D1.02.1	100	Y	GMT files with the velocities of the permanent GPS stations relative to a rigidly rotating Eurasia
1.02	Caporali A.	D1.02.2	100	Y	GMT files with strain rates at the center of clusters of permanent GPS stations in Italy and surrounding areas
1.03	D’Agostino N.	D1.03.A1	100		Values of the principal axes of the strain rate on a regular 0.05° grid
1.03	D’Agostino N.	D1.03.A2	100		Values of the geodetic moment rate on a regular 0.05° grid
1.03	D’Agostino N.	D1.03.A3	100		Angular velocities of the crustal blocks
1.03	D’Agostino N.	D1.03.A4	100		List of GPS stations used for the determination of the angular velocities
1.03	D’Agostino N.	D1.03.B1	100		Geodetic slip-rates of block boundaries
1.03	D’Agostino N.	D1.03.B2	100		Angular velocities of the crustal blocks defined in the block modeling
1.04	Devoti R.	D1.04.1	100		GPS time series of the Italian area
1.04	Devoti R.	D1.04.2	100		Reference frame of the italian area: coordinates, velocities, offsets of a selected subset of fiducial sites
1.04	Devoti R.	D1.04.3	100		Preliminary deformation field
1.04	Devoti R.	D1.04.4	100	Y	Final deformation field of the italian area: coordinates and velocities
2.02	Di Stefano R.	D2.02.1	100		3D P-wave and S-wave regional velocity model for Italy
2.02	Di Stefano R.	D2.02.2	100		Integrated model (regional model merged with the available very high definition local scale models)
2.02	Di Stefano R.	D2.02.3	100	Y	Updated map of the Moho topography, for the central Mediterranean region
2.02	Di Stefano R.	D2.02.4	100		Software package for 3D velocity model handling, and local best 1D extraction
2.02	Di Stefano R.	D2.02.5	100		Synthetic 3D P- and S-waves travel times calculation
2.04	Romanelli F.	D2.04.1	100		Database (suitable for GIS) containing the structural models vs. depth (~350 km) and uncertainties, for 1°x1° cells covering the Italian region
2.04	Romanelli F.	D2.04.2	100		Database (suitable for GIS) containing the refinement of the cellular models (with other optimization methods)
2.04	Romanelli F.	D2.04.3	100	Y	Relocation, source mechanisms and seismic moment (table format) for earthquakes with Mw≥4.8 in the Italian region
5.01	Aoudia A.	D5.01.1	100		Short term (decadal) slip rate of the Castrovillari fault
5.01	Aoudia A.	D5.01.2	100		Transient and time-dependent slip rate distribution over the Castrovillari fault plane
5.01	Aoudia A.	D5.01.3	100		Transients in the Cat-Scan CGPS
5.02	Crescentini L.	D5.02.1	100		ANGELA improvement, by adding capability to invert data for the slip distribution on the source fault in a layered medium, using the algorithm for the least squares problem with linear inequality constraints of Lawson and Hanson (1995)
5.02	Crescentini L.	D5.02.2	100		Further ANGELA improvement, by adding the capability to deal with listric faults, both uniform- and nonuniform-slipping
5.03	Megna A.	D5.03.4	100	Y	Model-predicted strain rate map

5.03	Megna A.	D5.03.5	100	Y	Model-predicted slip rate and fault kinematics

Management

The Task is rather diverse and not much has been and could be done in the way of coordinating activities within it. The only exception was represented by RUs 1.02, 1.03 and 1.04, all involved in GPS data analysis, which had a limited interaction during the second year of the project. Other RUs interact across Task boundaries (e.g. RU 1.02 with 1.01), suggesting that designing the Task structure is crucial to promote exchange among scientists without creating unexpected obstacles to the circulation of data and ideas.

Problems and difficulties

Some RUs participated in the rapid intervention teams that surveyed the epicentral region following the 6 April 2009 L'Aquila earthquake. This unplanned effort delayed the elaboration of the results and of some of the deliverables, at least during the first phase.

Some of the RUs faced difficulties related with the precarious nature of research contracts held by many of the most active scientists.

Finally, the leader of RU 1.04 pointed out that the full combination of all geodetic solutions is only possible if all analysis centers are willing to share their results and work in order to converge on homogenous formats and solution constraints. In contrast, throughout the project the participation to the definition of common standards and formats in the analysis of GPS data has been rather scarce. Some of the participants to the projects questioned whether the geodetic solutions should be made available immediately to the project partners to ease the comparison and combination processes, or if this should be done only after the results of each group have been properly published. As a result of this issue, different groups proceeded on their own paths, largely avoiding any exchange of ideas and methods. This problem was only partially overcome in the second phase of the project.

Main key publications

RU1.01

Braitenberg, C., Mariani, P., Grillo, B., Nagy I., 2009. Vertical crustal movements from comparative analysis of spaceborne and local sea level change observations – Sicily-Calabria, Italy. Submitted to Journal of Geophysical Research.

Braitenberg C., Mariani P., Tunini L., Grillo B. Nagy I., 2009. Vertical crustal movements from differential tide gauge observations with the control from satellite altimetry. Submitted to Journal of Geophysical Research.

RU1.02

Caporali, A., Barba S., Carafa, M.M.C., Devoti, R., Pietrantonio, G., Riguzzi, F., 2010. Static stress drop as determined from geodetic strain rates and statistical seismicity. Submitted to Journal of Geophysical Research, April 2010.

RU1.03

Avallone A., Selvaggi G., D'Anastasio E., D'Agostino N., Pietrantonio G., Riguzzi F., Serpelloni E., Anzidei M., Casula G., Cecere G., D'Ambrosio C., De Martino P., Devoti R., Falco L., Mattia M., Rossi M., Obrizzo F., Tammaro U., Zarrilli L., 2010. The RING network: improvement of a GPS velocity field in the central Mediterranean. Annals of Geophysics, 53 (2).

Serpelloni, E., Burgmann, R., Anzidei, M., Baldi, P., Mastrolembo, B., Boschi, E., 2010. Strain Accumulation Across the Messina Straits and Kinematics of Sicily and Calabria From GPS Data and Dislocation Modeling. Submitted to Earth and Planetary Science Letters.

RU1.04

Avallone A., Selvaggi G., D'Anastasio E., D'Agostino N., Pietrantonio G., Riguzzi F., Serpelloni E., Anzidei M., Casula G., Cecere G., D'Ambrosio C., De Martino P., Devoti R., Falco L., Mattia M., Rossi M., Obrizzo F., Tammaro U., Zarrilli L., 2010. The RING network: improvement of a GPS velocity field in the central Mediterranean. Annals of Geophysics, 53 (2).

Devoti R., Pietrantonio G., Pisani A. R., Riguzzi F. and Serpelloni E. 2010. Present day kinematics of Italy. In: (Eds.) Marco Beltrando, Angelo Peccerillo, Massimo Mattei, Sandro Conticelli, and Carlo Doglioni, The Geology of Italy, Journal of the Virtual Explorer, Electronic Edition, ISSN 1441-8142, volume 36, paper 2.

Devoti R., E. Flammini, G. Pietrantonio, F. Riguzzi, E. Serpelloni, 2009. Toward a dense Italian GPS velocity field: data analysis strategies and quality assessment, IAG Symposia series Ed. Sideris M.G., Springer, in press.

Riguzzi F., G. Pietrantonio, R. Devoti, S. Attori, M. Anzidei, 2009. Volcanic unrest of the Colli Albani (central Italy) detected by GPS monitoring test. Submitted to Physics of the Earth and Planetary Interiors.

RU2.02

Di Stefano, R., Castello, B., Chiarabba, C., Ciaccio. M.G., 2010. A detailed three-dimensional P-wave velocity structure in Italy from local earthquake tomography. Geophys. Res. Abstracts,12, EGU2010-14718, 2010, EGU General Assembly 2010.

RU2.04

Boyadzhiev, G., Brandmayr, E., Pinat, T., Panza, G.F., 2008. Optimization for non-linear inverse problems. Rendiconti Lincei 19, 17-43.

Brandmayr E., Guidarelli M., Panza G. F., 2008. INPAR Inversion of Earthquake Source Tensor of Major Italian Earthquakes Occurred in the Last Decade. Abstract presented at the ESC 2008, Crete (Greece), September 7-12 2008.

Brandmayr, E., Panza, G. F., Romanelli, F., 2009. Structure and thickness of the lithosphere in Italy from tomographic and moment tensor non-linear inversion studies. Abstract presented at the EGU 2009, Wien (Austria), April 20-24 2009.

Brandmayr, E., Raykova, R., Zuri, M., Romanelli, F., Doglioni, C., Panza, G., 2010. The lithosphere in Italy: structure and seismicity. In: (Eds.) Marco Beltrando, Angelo Peccerillo, Massimo Mattei, Sandro Conticelli, and Carlo Doglioni, Journal of the Virtual Explorer, volume 36, paper 1, doi: 10.3809/jvirtex.2009.00224.

Zuri, M., 2009. Proprietà meccaniche cellulari della litosfera della regione italica, Tesi di Laurea in Scienze Geologiche, Università degli Studi di Trieste.

RU5.01

Aoudia, A., 2009. Length and time scales of the continental deformation: a lithosphere-scale rock mechanics experiment. Abstract presented at the IASPEI 2009 Conference, Cape Town (South Africa), January 11-16 2009.

Sabadini, R., Aoudia, A., Barzaghi, R., Crippa, B., Marotta, A.M., Borghi, A., Cannizzaro, L., Calcagni, L., Dalla Via, G., Rossi, G., Splendore, R., Crosetto, M, 2009. First evidences of fast creeping on a long-lasting quiescent earthquake normal-fault in the Mediterranean, Geophysical Journal International, Volume 179, 2, 720-732.

RU5.02

Amoruso, A., Barba, S., Crescentini L., Megna A., 2010. Inversion of synthetic geodetic data for planar fault events: clues on the effects of lateral heterogeneities and model selection, Abstract presented at the EGU 2010 Conference, Vienna, 2-7 May.

Crescentini, L., Amoruso, A., 2009. Source fault parameters and slip distribution: the importance of crustal layering for the 1908 Messina Straits earthquake, Abstract presented at the EGU 2009 Conference, Vienna, 19-24 April.

RU5.03
Barba, S., Carafa, M.M.C., Mariucci, M.T., Montone, P., Pierdominici, S., 2008. Active stress field modelling in the southern Apennines (Italy) using new borehole data, 3rd World Stress Map Conference, 15-17 October 2008 in Potsdam, Germany.
Barba, S., Basili, R., Carafa, M.M.C., Balestra, F., 2008. Depth of the seismogenic layer in Italy, AGU Fall Meeting, 15-19 December 2008**,** San Francisco, California.
Barba, S., Carafa, M.M.C., Mariucci, M.T., Montone, P., Pierdominici, S., 2008. Active stress field modelling in the southern Apennines (Italy) using new borehole data. Submitted to Tectonophysics.
Barba, S., Carafa, M.M.C., Boschi E., 2008. Experimental evidence for mantle drag in the Mediterranean, Geophys. Res. Lett., 35, L06302, doi:10.1029/2008GL033281.

Task B: Earthquake Data and Statistics

Task information

Task B
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Progress of the task: general

This task coordinates the RUs of project S1 that are aimed mainly to i) improve the knowledge of Italian seismicity and ii) characterize the statistical properties of seismic generation in Italy.
In particular the availability of a homogeneous and complete seismic catalog is a prerequisite for most analyses. This issue was pursued at a national scale by RUs 2.01, 2.05, S.01 and 4.02 and at regional scale by RU 2.03, while RUs S.02, S.03, S.04 and 4.01 were only possible users of the revised catalog. A preliminary version of the revised instrumental catalog from 2003 to 2007 has been released by RU 2.01 but it does not include homogeneous Ml magnitudes from simulated Wood-Anderson (SWA) waveforms. It will be possibly released in the next weeks or months but this prevented the completion of some statistical analyses before the end of the project.

Progress of the task by RUs

Tables and figures regarding the various activities can be found in relevant reports by the RUs.

1.1.1 RU 2.01 (Resp. Chiarabba)

The retrieving of phase arrivals from various seismic networks as well as the merging of the data and the association of phases has been completed for the time range 2003-2007. Most of the time was spent for the latter activity that required the development of specific computational codes. The location strategy was modified with respect to the planned one with the moving from a multiple location approach (with different initial parameters) to a 3D earthquake location based on a high resolution 3D regional velocity model produced by S1-UR 2.02. The well tested, and stable tomographic inversion code, SimulPS14 by Haslinger, F. (1998) was used to locate earthquakes in 3D. ML computation is still in progress, Ml based on regression law by Castello et al. (2007), is attributed from durations retrieved by bulletins of regional and national permanent seismic networks, when they are available. A second preliminary version of the 2003-2007 update of CSI 2.0 (Deliverable D2.01.1) have been produced at the end of the project but still it does not include the Ml magnitudes from SWA waveforms.

1.1.2 RU 2.03 (Resp. Neri)

The second phase of the Project has been devoted almost entirely to the analysis of the space distributions of the recent seismicity in Calabria and Sicily located by using the 3D velocity model of the entire Southern Tyrrhenian region obtained during the first phase of the Project (Deliverable D2.03.1). Hypocenter locations (deliverable D2.03.02) have been performed by classical inversion algorithms like those of the Simul series (Evans et al., USGS-of 1994) and by the Bayloc non-linear probabilistic algorithm (Presti et al., BSSA, 2004). This method has been shown to help detection of the seismogenic structures through more reliable estimation of location errors compared to linearized methods like Simulps.
The spatial distribution of probability density relative to a set of earthquakes, computed by Bayloc as the sum of probability density functions of the individual events, have been compared with other seismological (e.g., focal mechanisms) and geological (e.g., main fault structures) data in order to obtain a more complete view of the seismic behaviour in the investigated sectors (deliverable D2.03.3). The attention was focused on longitudinal structures of the Arc located west of the chain in Southern Calabria (Messina Straits, Gioia Basin and Mesima Valley), in Northern Calabria (Albi-Cosenza) as well as to the seismically active area in Sicily between Cefalù and Mt Etna. In some cases the analyses allowed to identify significant trends that can be considered as signatures of seismogenic structures.

1.1.3 RU 2.05 (Resp. Vannucci)

Boxer code was notably improved by introducing: *i*) 6 new methods (using the radiation center approach, i.e. using an attenuation law) for the location of the macroseismic epi/hypocenter beyond the "classic" approach (barycenter method) of the version 3.3 (Gasperini et al., 1999); *ii*) a new method for computing the magnitude, also based on an attenuation law; *iii*) assessment of uncertainties of all the computed parameters using both formal methods and the bootstrap approach (deliverable D2.05.1). All the details for the methodology, as well as the discussion of the results are described in a paper (Gasperini et al., 2010) currently in press on the BSSA. A new version (4.0) of Boxer code has been released and distributed among a group of selected users for beta-testing. The final release of the code, which also includes a user-friendly interface for parameter setting and the plotting of the results, will be made available to the entire scientific community before the publication of the paper (expected in October 2010).
The EMMA (Earthquake Mechanisms of the Mediterranean Area) database was improved by adding further mechanisms taken from the literature (deliverable D2.05.2). At present time it collects 12258 focal solutions, twice than the last public version 2.2 (Vannucci and Gasperini, 2004). As for the previous versions (Vannucci and Gasperini, 2003, 2004), the focal solutions are checked to verify the consistency among nodal planes and/or axes. When inconsistencies and misprints are found, these are corrected and recovered (if possible). The usable focal solutions are 11864.
New fields are introduced to immediately correct possible misprints or obvious mistakes of input data and new approaches are introduced to establish the "preferred" solution when more than one focal mechanism is available, from different sources and authors, for the same events. A kit in MS-ACCESS is available to manage the EMMA data, based on the same platform of previous versions, using the new weights for the preferred solution and the verified field. The complete EMMA database is also provided in a MS-EXCEL version. A web-based version (deliverable D2.05.3) is still in progress.

1.1.4 RU 4.01 (Resp. Lavecchia)

The research activity was aimed to identifying and constraining the individual seismogenic sources responsible for the major earthquakes of the Maiella and Abruzzo foothill areas (deliverable D4.01.1):

1-Maiella, November 3, 1706 Imax X/XI MCS (CFTI4Med, Guidoboni et al., 2007), Maw6.6 (CPTI04 by Gruppo di Lavoro CPTI, 2004), Mwm 6.83, (CPTI10beta by Rovida et al., 2010);
2-Maiella, September 26, 1933 Imax IX MCS (CFTI4Med), Mwm 5.97 (CPTI10beta);
3-Southern Abruzzi, September 10, 1881 ImaxVIII MCS (CFTI4Med), Mwm 5.59 (CPTI10beta).
In order, to highlight a possible earthquake-seismogenic source association, a recently defined search-grid inversion method, which has already resulted to be successful in other areas of central Italy (de Nardis, 2008; de Nardis et al., 2010), has been applied to the events which strike in the area and are associated with many and well studied felt intensity points.
Available geological and geophysical information are considered to select all the realistic input seismogenic fault models and to identify, for each of them, a 3-D space of variability of the individual source parameters. Synthetic peak ground motion waveforms are simulated at any site of the macroseismic field and converted into intensities using empirical relations. In order to analyze the 1706 earthquake, the most significant one in the Maiella region, transfer functions deduced from the analysis of the surface geological information and of microtremor measurements were introduced in the calculation. The inversion was carried out by minimizing the data distance between the calculated and the observed intensity values, using the L1 norm. The accuracy of the simulated macroseismic field into reproducing the real one is assessed by estimating the misfit reduction respect to the total and partial macroseismic field. The inversion results are also compared with a solution calculated using a seismic intensity attenuation law.
Based on a structural analysis of possible active structures the following fault models are adopted for the comparison with inversion results.

1. Abruzzo Citeriore Basal Thrust (ACBT - Model 1): strike 135±10, dip 23±5, seismogenic layer 0-25 km;
2. Maiella Basal Detachment Model (MBD - Model 2): strike 15±10, dip 25±5, seismogenic layer 0-15 km;
3. Morrone-Porrara Normal Fault Model (MPNF - Model 2): strike 145±10, dip 50±5, seismogenic layer 0-15 km;
4. Caramanico Normal Fault Model (CNF - Model 3): strike 160±10, dip 60±5, seismogenic layer 0-12 km;
5. Strike-Slip Fault Model (SSF - Model 5): strike 95±10, dip 75±5, seismogenic layer 5-20 km.

The obtained inversion results (see Table 4 of RU report) indicate that the ACBT fault model is the only structure among the modeled ones capable to well reproducing, at the same time, both the high and the low intensity macroseismic field of both the 1706 and 1933 earthquakes. In particular, the ACBT best modeled finite fault would have activated a portion of the thrust plane, at depths between 10 and 16 km during the 1706 event and a contiguous portion, at depths between 11 and 9 km during the 1933 event. Both fault segments would be located within the middle crust, mostly the Paleozoic-Triassic sequence and the underlying crystalline basement. The source of the 1881 event might be located along the same thrust at upper crustal depths (3-5 km) or otherwise within an E-W strike slip fault within the ACBT footwall. The inversion result did not allow to discriminate among the two solutions.
It can be hypothesized that although the level of the compressional seismic activity in the study area might appear low, a long-term strength might reside in the whole crust and occasionally concentrate along discrete reverse shear zones corresponding to narrow planar strain domains which juxtapose crustal blocks (Pili et al., 1997 and references therein).

1.1.5 RU 4.02 (Resp. Palombo)

The RU4.02 analyzed 20 events of magnitude ranging between 3.8 and 7.5, selected with the main aim of giving a contribution to knowledge of historical earthquakes located in the sea or in areas where macroseimic data are poor for a reliable location and sizing.

Instrumental locations were estimated by the NonLinLoc software (Lomax, 2005). The algorithm calculates a probabilistic solution based on a grid-search to obtain an estimate of the probability distribution function in a three-dimensional space using the P and S phases of the waveforms. The phases for the locations were extrapolated from the historical seismograms, wherever possible, integrated by the data drawn from the seismic bulletins (ISS, BCIS, ISC) and from those of the individual stations (deliverable D4.02.1).
Seismic scalar moments were computed by the method of Brune (1970, 1971) and that of Tsuboi (1995). Following Brune (1970), the seismic moment Mo is roughly proportional to the low-frequency level of the far-field spectrum. Tsuboi (1995) considers the scalar moment at each station proportional to the integral of the displacement of the P-wave portion of a broadband seismograph record. As we observed anomalies of the power spectra around 0.1 Hz, which may result in unreliable magnitude estimations, we preferred to derive Mo following Tsuboi (1995), although only vertical seismograph components can be used in this method. The data available allowed to applying the Tsuboi method with good results only to the 1930 Senigallia (Mw=6.3+0.2) and 1933 Maiella (Mw=6.4+0.3) earthquakes.
During the project the RU4.02 started writing software for the calculation of the moment tensor, as previously described in the first year report. The program is still in the development phase and is undergoing the preliminary tests, only the focal mechanism from the polarities of the first P and S arrival points have been computed.

1.1.6 RU S.01 (Resp. Gasperini)

The activities related to the compilation of a new instrumental catalog of Italy were delayed due to the unavailability of a preliminary catalog from 1981 to 2007 including Ml magnitude computations (see above). However, the RU proceeded with some propaedeutical activities. These include the computation of empirical relationships between moment magnitude e other types of magnitude. The obtained coefficients were used to compile a database of 669 homogeneous moment magnitude estimates for earthquakes occurred in the Italian region from 1901 to 1980 that also include 421 instrumental locations derived from the literature and from international agencies (ISC, PDE etc.) that have been checked for reliability (deliverable DS.01.1). These data contributed to the last version of the historical catalog CPTI10beta recently released by the INGV for beta-testing.
A completeness analysis of existing instrumental datasets available for the time interval 1981-2009 have also been completed (deliverable DS.01.2). These datasets are including the CSTI 1.1 Catalog from 1987 to 1996, the CSI 1.1 Catalog from 1997 to 2002 and the INGV on-line seismic Bulletin, divided in two periods from 2003 to 15/4/2005 and from 16/4/2005 to 2009. We found significant differences both for the completeness magnitude thresholds and for the Gutenberg-Richter *b*-values. The full application of such technique to the instrumental catalog from 1980 to 2007 will be implemented as soon as such catalog will be made available by RU 2.01.
The RU also collaborated with RU 2.05 to the integration between the instrumental catalogs and the database of Earthquake Mechanisms of the Mediterranean Area (EMMA). This work has been not completed yet, particularly regarding the manual checking of associations. However, the recently released version of the EMMA database (see Report of RU 2.05) includes additional fields with the location taken from hypocentral catalogs. The collaboration with RU 2.05 also concerned the development of new methods of location and sizing of earthquakes based on macroseismic data. This activity brought to the release of a new version of Boxer code (4.0) that is currently in beta-testing within a group of selected users.
A significant effort was also given to the analysis of the aftershock sequence of the 6 April 2009 earthquake. A study on the variations of aftershock decay properties with time showed that the first few days, the decrease of the rate appears very slow, compatible with an Omori's process with power-law exponent $p \approx 0.5$. The progressive increase of the exponent up to about $p=1.2$ in the following weeks can be interpreted as the emergence of a negative exponential regime that has been found by previous work of this RU to control the decay of other sequences occurred in Italy and

California. In the first two months after the main shock the evolution of the sequence does not show an evident epidemic character, as strongest aftershocks do not seem to have induced significant increases of the aftershock rate while a couple of them seem to be preceded, rather than followed, by a slight increase of the rate. It was also shown that the L'Aquila main shock is one of the most productive ever observed in Italy, as it produced from 3 to 10 times more aftershocks that any previous earthquakes with similar magnitude.
The statistical evaluation of seismic occurrence/recurrence models (Characteristic earthquake, Time- and Slip-predictable, Brownian Passage Time, Strain acceleration, etc.) (deliverable S.01.3) was deferred to later times due to the unavailability of the homogeneous instrumental catalog.
The development of software for the representation of the probability of occurrence of aftershocks in near real-time (deliverable DS.01.4) has been undertaken but not completed yet due to the focusing on the study of the properties of the decay of the L'Aquila sequence.

1.1.7 RU S.02 (Resp. Rotondi)

This RU has given a contribution towards long-term seismic hazard through two stochastic tools: self-correcting models and renewal process, both combined with the geological data base DISS, version 3.0.2, whose potential seismogenic sources were aggregated in eight macro-regions MR according to their tectonic regime. Earthquakes of magnitude $M_w \geq 5.3$ have been drawn from the historical parametric CPTI04 catalogue of Italy and associated with each seismogenic source (SA) of DISS, forming in this way eight data sets. The eight macro-regions – Western and Eastern Alps, Central Eastern and Western Apennines, Southern Eastern and Western Apennines, Calabrian arc, Sicily – have been considered seismic units on the basis of the kinematic context and the expected rupture mechanism.
1) Self-correcting models
For each of the eight macro-regions different versions of the stress release model and of a new point process model based on the slip rate have been analyzed. Their conditional intensity function – instantaneous occurrence probability (= hazard function) have been estimated (deliverables DS.02.1.1, DS.02.1.2, DS.02.1.3, DS.02.2.1, DS.02.2.3). The probability distribution of the time of the next event has been simulated for each model and for each macro-region (deliverable DS.02.4) by inverting the corresponding cumulative intensity function (integrated hazard function). Repeating many times this simulation, a sequence of occurrence times have been obtained; its mean value is adopted as the forecast time of the next event whereas the probability density is estimated through a nonparametric kernel method. Moreover, according to the Bayesian approach, the Bayes factor as quantitative measure of the evidence in favor of a model have been evaluated.
In addition the stationary Poisson process have been considered as limit case: all the estimates like those given for the previous models, but characterized, in this case, by constant seismicity rate and exponential probability distribution of the inter-event time with parameter equal to the constant rate are provided (deliverable DS.02.5).
2) Renewal process
A three-step procedure consisting of exploratory analysis, prior assigning and estimation constitute is applied to each of the four data sets built by partitioning seismogenic areas. From each set, the estimate of a probability density of the inter-event time in each macro-region and a table with the occurrence probabilities in each seismogenic area within years 2012, 2022, 2032, 2052, 2102 have been obtained (deliverable DS.02.3). The best match with the three earthquakes recorded from 2003 is given by the data set obtained by partitioning the DISS3.0.2 SA 27 (Viareggio-Val di Lima-Bologna line and Conca line) in three parts, the SA 37 (Conca-line and Fossato di Vico-Valle dell'Esino line) in two and leaving SA 25 (Ancona-Anzio line) unchanged.

1.1.8 RU S.03 (Resp. Slejko)

The project is subdivided into 4 activities: the first three are strictly linked together and are then described together. During the first year of the project, the methodology for characterizing the seismicity in the seismogenic sources and for validating the parameters of the Gutenberg-Richter (G-R) relation were defined and applied to the 4 domains covering Italy on the basis of the available geodetic data. During the second year, 8 macroregions, homogeneous from the seismotectonic point of view have been considered and the occurrence probability of strong earthquakes has been computed, repeating the defined methodology (deliverable DS.03.1).
Entering into details, the seismicity rates of each macroregion have been computed by the Albarello and Mucciarelli approach, and the parameters of the G-R relation. The strain rate computed on the basis of GPS data by the RU 1.02 (Caporali) for the seismogenic zones of the ZS9 national zonation has been considered as basic information for the geodetic contribution. The percentage of aseismic creep in each macroregion has been calculated as ratio between this geodetic moment rate and the seismic moment rate, estimated as complete G-R distribution of the seismicity in each macroregion. The occurrence probability for $M \geq 6.0$ and 6.5 has been computed considering a time independent approach (Poisson).
Activity 4 of the present research aimed at investigating about the possible relations between variations of the local strain and geochemical anomalies in north-eastern Italy. Several water springs were monitored regularly (deliverable DS.03.2), the increase in time of the strain at the water spring locations, deducted a posteriori from the earthquake parameters and the regional strain rate, has been compared with the anomalies pinpointed by the geochemical quantities. The results indicate that parameters such as temperature, redox potential, pH, bicarbonate and sulfate content show generally a non random behaviour, which is attributed to seasonal processes and/or mixing between different aquifers at variable extent. It is hence believed that these parameters cannot be used as reliable geochemical tracers of fault-induced processes. On the contrary, accordingly to their conservative character, chloride and Rn changes are invariably related to random phenomena, and have been interpreted in terms of the possible involvement of fluids in faulting processes. The observed Rn and chloride geochemical signals have been related to the role of deformation in enhancing mineral reactions and micro-fracturing at crustal level, including diagenetic processes affecting the gauge permeability and producing abnormally high fluid pressure within sealed rock pores. The development of the fracture network along compressive structures in response to strain changes results in the expulsion of such pore fluids, which move rapidly from the overpressured to the hydropressured zones of the fault gauge and are recorded as short-living chemical zonations at the groundwater outlets. The observed sharp increase in the chloride concentration observed for some of the springs has been modeled by considering the role of reactions involving the properties of clay minerals to entrap chloride ions into the pore spaces, followed by expulsion during deformation and compaction. In this way, the chloride concentration in the pressure effluent becomes higher than in the original solution. The proposed model has been finally coupled with the strain changes computed at the proper site.

1.1.9 RU S.04 (Resp. De Rubeis)

A study of the spatial and temporal variation of the earthquakes clustering and rate decay was developed (deliverables DS.04.1, DS.04.2). We used an Italian seismic catalogue, characterized by specific spatial and magnitude ranges (INGV CSI 1981-2002 and ISIDE 2002-2009). A stacking procedure has been applied to characterize a typical sequence behavior and allowing the evaluation of changes over time intervals and distances from the main shock. The resulting decay rate has values comparable to the modified Omori law with $p=1$ at small distances and inside specific time ranges. At short times after the mainshock (<10-20 days) the slope p is small before reaching the typical value $p \approx 1$. The slope of the first period increases with increasing threshold magnitude. This

dynamics highlights the importance of looking at proper space-time limits when analyzing the seismic decay after a main shock.
Concerning the space correlation dimension, results reveal the presence of a space clustering of hypocenters for distances greater than few tens of *km* and for time intervals less than hundreds of days. At short distances hypocenters are time clustered but there is not space clustering. This zone is probably due by the activity of seismicity on the seismic fault.
Macroseismic fields, of five relevant Italian Regions, have been analyzed. Data were collected from on-line macroseismic questionnaire and refer to medium-low magnitude events. We evidenced non isotropic intensity residuals for all cases analyzed and in agreement, for L'Aquila main event, with ground motion parameters
In another study, intensity data were fitted with the logarithm of hypocentral distance and compared with averages computed over a moving time window. The logarithmic function showed to fit well intensity data, as compared with moving window averages. The intensity residuals, obtained subtracting, from original intensity data, the isotropic intensity field coming from attenuation fit, show regional variations that might be related to both the geological setting of the territory and the source mechanisms (deliverable DS.04.3).
Intensity data evaluation was also performed at a very local (urban) scale, integrating for the town of Rome the data of the main events pertaining the L'Aquila sequence coming from about 3700 on-line questionnaires. Seismic amplification and attenuation areas are evidenced probably connected to local geological setting (i.e. alluvial river deposits).

Deliverables

D2.01.1 Catalogue of instrumental seismicity (2002-2007), preliminary version to be used within the project: **100%**
D2.01.2 Seismic catalogue for the Italian territory (CSI 2.0): earthquake locations with regional velocity models and magnitude **80%**
D2.03.1 3D crustal seismic velocity models for eastern Calabria and western Sicily **100%**
D2.03.2 Databases of hypocenter parameters of the crustal seismicity occurring in eastern Calabria and western Sicily during 1981-2007 **100%**
D2.03.3 Detailed investigations of the most significant seismic phases and/or of the main clusters of seismicity in eastern Calabria and western Sicily, as contributions to the parametrization of the seismogenic structures **100%**
D2.05.1 New release of Boxer code including a user-friendly interface **100%**
D2.05.2 New upgraded version of EMMA database **100%**
D2.05.3 Web version of EMMA database **50%** (EMMA is 100% available in the S1-project webgis)
D4.01.1 Source parameters on the likely seismogenic sources of the the Maiella and Abruzzi foothill earthquakes of 1706, 1881, 1882, 1933, 1950 **100%**
D4.02.1 Tables of seismic parameters (location, magnitude, focal mechanisms, seismic and geodetic deformation rates) for the earthquakes found in the Adriatic coast area, in the Calabrian area, and in the Central Latium (1919 Anzio earthquake) **100%**
DS.01.1 Homogenized instrumental catalog from 1980 to present (and possibly extended to the entire XX century). **90%**
DS.01.2 Completeness threshold of instrumental and historical catalog for different time intervals. **80%**
DS.01.3 Validation of models of seismic occurrence for the Italian catalog. **30%**
DS.01.4 Computing code for the estimate of the probability of occurrence of aftershocks in near real-time. **70%**
DS02.1.1 - Occurrence probability in the tectonic regions MR and some seismogenic areas SA according to the seismic slip model in which rupture area = seismogenic area **100%**

DS02.1.2 - Occurrence probability in the tectonic regions MR and some seismogenic areas SA according to the seismic slip model in which rupture area = regression by Wells and Coppersmith (1994) **100%**
DS02.1.3 - Occurrence probability in the tectonic regions MR and some seismogenic areas SA according to the seismic slip model in which rupture area = sum of the areas of the region **100%**
DS02.2.1 - Occurrence probability in the tectonic regions MR and some seismogenic areas SA according to the stress release model on the basis of the Benioff strain **100%**
DS02.2.2 - Occurrence probability in the tectonic regions MR and some seismogenic areas SA according to the stress release model on the basis of the seismic moment **100%**
DS02.3 - Estimation of the probability density function of the recurrence time and approximation of the occurrence probability at different forecasting horizons for seismogenic areas according to renewal process **100%**
DS02.4 - Simulation of the time of the next event with credible intervals according to the stress release model in the tectonic regions MR and some seismogenic areas SA **100%**
DS02.5 - Occurrence probability for the Poisson model in the tectonic regions MR and some seismogenic areas SA **100%**
DS.03.1 Form for the seismogenic sources with Mmax/Mchar, occurrence probability with confidences **100%**
DS.03.2 Water geo-chemistry database **100%**
DS.04.1 Report on space-time clustering behavior of seismicity of Italian Region **100%**
DS.04.2 Report on spatio-temporal characterization of italian seismicity: definition of correlation and clustering ranges **100%**
DS.04.3 Report on macroseismic anomalous attenuation zones of Italian Region **100%**

Problems and difficulties

RU 2.01 encountered difficulties in acquisition of arrivals phases from all institutions. Still there is not a homogeneous format to shared phases arrivals data. The velocity model provided by RU 2.02 needed carefully application of pre and post-processing location procedures. Magnitude data-acquisition was found to depending strongly from locations catalogue, magnitude computations were delayed.
RU 2.05 found difficulties to assign a weight or quality factor for each available focal solution of the EMMA database due to the variability of parameters furnished by different authors. Moreover he link between each focal solution and the corresponding earthquake in available catalogs required a manual check due to the huge amount of data to merge: in many cases automatic criteria do not provide a single link with hypocentral parameters.
RU 4.01 did not study the 1950 Gran Sasso earthquake (which had been inserted among the group of sources to be investigates), as it is located northward of the investigated area, in a partially different seismotectonic context. On the other side, it applied twice the entire inversion procedure to the 1706 earthquake.
RU 4.02 had several kinds of problems. The first one regards the difficulty in retrieving the original paper seismograms and instrument parameters, particularly for events that had occurred in period of war. The second one regards the method for calculating the focal mechanism. It can be computed using the polarity of the P-wave arrival or using the moment tensor inversion techniques, which also provide a moment magnitude estimation.

RU S.01 was not able to complete part of planned activities due to the unavailability of the instrumental catalog for the period 1981-2007 that RU 2.01should have provided by the end of third semester.
RU S.03 encountered problems to reach some springs in winter without requiring changes on the original plans.

Main key publications

RU 2.01

Billi A., Presti D., Orecchio B., Faccenna C., Neri G., 2010. Incipient extension along the active convergent margin of Nubia in Sicily, Italy: the Cefalù-Etna seismic zone. Tectonics, in press.

RU 2.03

Neri, G., Marotta, A.M., Orecchio, B., Presti, D., Totaro, C., Barzaghi, R., Borghi, A., 2010. How lithospheric subduction changes along the Calabrian Arc in southern Italy: geophysical evidences, sottomesso a Geophysical Journal International.

Neri, G., Marotta, A.M., Orecchio, B., Presti, D., Totaro, C., Barzaghi, R., Borghi, A., 2009. How lithospheric subduction changes along the Calabrian Arc in southern Italy: geophysical evidences. Abstract presented at XXVIII Convegno Nazionale del G.N.G.T.S., Trieste, 16-19 Novembre.

Neri, G., Orecchio, B., Presti, D., Totaro, C. 2010. Defining a new 3-D lithospheric velocity model of the Calabrian Arc region (Southern Italy) from the integration of different seismological data. In: Geophysical Research Abstracts Vol 12, EGU General Assembly 2010 Vienna, 02-07 Maggio.

Orecchio, B., Presti, D., Totaro, C., Guerra, I., Neri, G., 2010. Imaging the velocity structure of the Calabrian 1 Arc region, submitted to Bolletino di Geofisica Teorica ed Applicata.

Orecchio, B., Presti, D., Totaro, C., Guerra, I., Neri, G., 2009. Tomographic imaging of P- and S-wave velocity structure beneath the Calabrian Arc region (south Italy): an improved view of the subduction system. Abstract presented at XXVIII Convegno Nazionale del G.N.G.T.S., Trieste, 16-19 Novembre.

RU 2.05

Gasperini P., Vannucci G., Tripone D., 2009. A new version of "Boxer" code for the determination of seismic source parameters from macroseismic data. Abstract presented at the EGU 2009 Conference, Wien (Austrian), 2009 April 20-24.

Gasperini P., Vannucci G., Tripone D. and E. Boschi, 2010. The location and sizing of historical earthquakes using the attenuation of macroseismic intensity with distance, Bull. Seism. Soc. Am., in press

Vannucci G., Imprescia P., Gasperini P., 2008. EMMA (Earthquake Mechanisms of the Mediterranean Area) versione 3.0: Uno strumento utile per la caratterizzazione sismotettonica dell’area mediterranea Abstract (Sezione 1.1 Processi tettonici: osservazioni e modelli) presented at the XXVII Convegno del Gruppo Nazionale Geofisica della Terra Solida, Trieste (Italy) 2008 October 6-8.

Vannucci G., Imprescia P.,Gasperini P., 2009. Earthquake Mechanisms of the Mediterranean Area (EMMA) version 3: an improved tool for characterizing the tectonic deformation styles in the Mediterranean. Abstract presented at the EGU 2009 Conference, Wien (Austrian), 2009 April 20-24.

RU 4.01

Lavecchia, G., de Nardis, R., and Ferrarini, F. Destructive compressional earthquakes in central Italy - an evaluation of geologically-constrained available options for scenario earthquake fault ruptures in the eastern Abruzzi region, to be submitted to Geological Society of America Bulletin.

de Nardis, R. and Lavecchia, G., Search-grid inversion-based investigation for the seismogenic sources of historical earthquakes: the Maiella 1706 (Mw 6.8) case study, Central ITALY, to be submitted to Bulletin of the Seismological Society of America

de Nardis, R., Garbin, M., Lavecchia, G., Pace, B., Peruzza, L., Priolo, E., Romanelli, M., Romano, A., Vesnaver, A., Visini, F., and Vuan, A., 2009, Studio integrato sismlogico e geologico-

strutturale dell'area abruzzese a SW del Massiccio della Maiella (poster). XXVIII Convegno Nazionale del GNGTS, Trieste, Italy, November, Volume dei Riassunti Estesi 16-19 .
Lavecchia, G. and de Nardis, R., 2009a, Seismogenic sources in the Maiella area: constraints from geological data, historical and instrumental seismicity, in Proceedings, Italian Earth Science Forum, 7°th, Rimini, September, 9-11, 2009, Epitome, Volume 3, p. 183.

RU 4.02

F. Bernardi, M.G. Ciaccio, I. Hunstad, B. Palombo, G. Ferrari, 2009. The correlation between Historical and Instrumental Seismicity in the Sansepolcro basin, Northern Apennines, Italy. EGU 2009, Vienna.

RU S.01

Lolli B., Boschi E. and Gasperini P. (2009). A comparative analysis of different models of aftershock rate decay by maximum likelihood estimation of simulated sequences, J. Geophys. Res., 114, B01305, doi:10.1029/2008JB005614.
Lolli B., Gasperini P. and Boschi E., (2010) Time variations of aftershock decay parameters of the April 6, 2009 L'Aquila (Central Italy) earthquake: evidence of the emergence of a negative exponential regime superimposed to the power-law, Geophys. J. Int. (under revision).
Gasperini P. and Lolli B. (2009) An empirical comparison among aftershock decay models, Phys. Earth Plan. Int. doi:10.1016/j.pepi.2009.03.011.

RU S.02

Rotondi, R., Varini, E., 2009. Time-dependent seismic hazard assessment through a self-correcting point process for the slip", Abstract presented at the General Assembly of European Geosciences Union, Vienna, April 19-24 2009.
Rotondi R., Varini E., 2009. Bayesian estimation of the conditional intensity function in self-correcting point processes applied to the seismic activity of Italian tectonic regions, The 20th Annual Conference of the International Environmetrics Society, a Section of the ISI and GRASPA Conference 2009, Bologna, July 5-9 (invited speaker).
Varini E., Rotondi R., Betrò B., Barba S., Basili R., 2009. Self-correcting models for seismic hazard assessment in comparison, Atti del 28° Convegno Nazionale del Gruppo Nazionale di Geofisica della Terra Solida (GNGTS), Ed. Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, 414-416, Trieste, November 16-19.

RU S.03

Slejko, D., Caporali A., Stirling, M. Barba, S., 2010. Occurrence probability of moderate to large earthquakes in Italy based on new geophysical methods. J. Seismol., 14: 27-51, DOI 10.1007/s10950-009-9175-x.
Slejko, D., Petrini, R., Riggio, A., Slejko, F.F. Santulin, M., 2009. Possible relationships between strain, radon degassing and fluid geochemistry in tectonically active regimes: preliminary results from the Friuli – Venezia Giulia region (NE Italy). In: Gruppo Nazionale di Geofisica della Terra Solida, 28° Convegno Nazionale, Riassunti estesi delle comunicazioni (edited by D. Slejko and A. Rebez), Stella Arti Grafiche, Trieste, pp. 420-423.

RU S.04

P. Sbarra, Tosi P and De Rubeis V. 2009. Web based macroseismic survey in Italy: method validation and results. Natural Hazard DOI: 10.1007/s11069-009-9488-7.

De Rubeis V, P. Sbarra, Sorrentino D. and Tosi P. 2009. Web based macroseismic survey: fast information exchange and elaboration of seismic intensity effects in Italy. International Journal of Emergency Management Vol. 6 Nos. 3/4 pp 280-294.

P. Sbarra, Tosi P, De Rubeis V and Ferrari C. 2009. Web based macroseismic survey of 2009 L'Aquila earthquakes sequence. EMCS Newsletter Dec 2009, 24, 34-36.

Task C: Earthquake Geology

Task information

Task C Earthquake Geology
Task leader: Roberto Basili
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Progress of the task: general

The main goal of this Task was to collect data to characterize the geometric and kinematic properties of seismogenic structures and contribute at estimating the overall seismic potential of the Italian territory. As reported by all RUs, this commitment, in terms of activities done, was almost entirely fulfilled. The rate of achievements with respect to plans is very high.

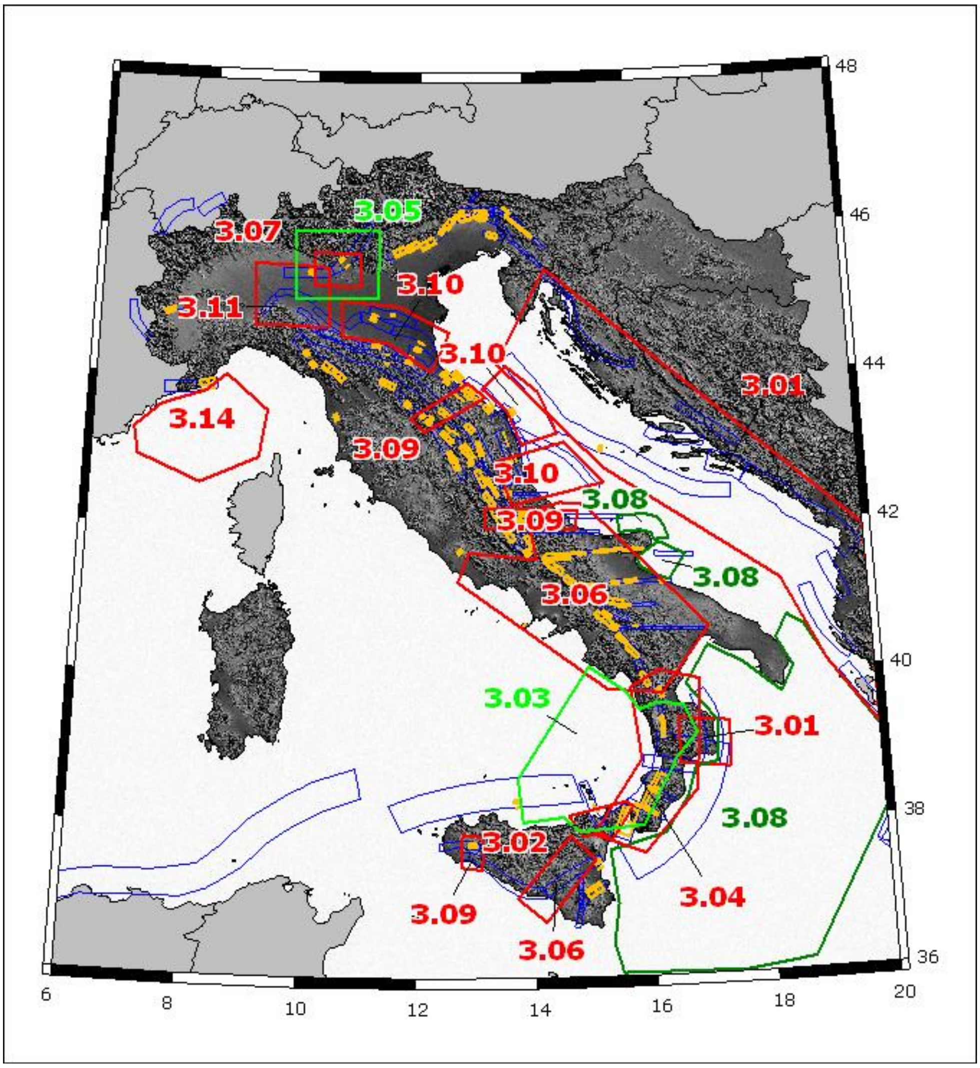


Figure 20: Map of the areas investigated by RUs in this Task (polygons with labels). Areas covered by RU3.06 concern point data of borehole breakouts. RUs 3.01, 3.06, 3.12, and 3.13 gave nationwide contributions. Yellow and blue polygons mark respectively the "individual" and "composite" seismogenic sources as in DISS 3.0.4 (latest release before the project, see RU3.12 for DISS updates).

The main strength of the work is the acquisition of a fairly good amount of data in regions of the country that had not been thoroughly explored in the past from the earthquake geology point of view (see Figure 20). Also, data collection was carried out at very different scales of observation (seeTable 4). This is especially the case for the zones offshore where only highly expensive and time-consuming geophysical exploration can bring about novel data and knowledge. Industrial seismic exploration data recently released to the public formed a wide and useful basis to complement the efforts of this project and future efforts as well. On land, geological field data acquisition was also mainly directed in areas poorly explored in the past. Worth of notice is the Southern Alps area near Brescia and Como where paleoseismological studies brought about evidence for a few coseismic surface ruptures in contractional tectonic structures in Italy. This is a rare issue because most of the active thrusts are buried below the Po Plain thick alluvial deposits or lay offshore in the Adriatic and Ionian Seas. Particularly in the Ionian Sea, unprecedented results were obtained through mapping of active tectonic structures, potentially seismogenic, in the accretionary wedge of the Calabrian Arc.

One of the main opportunities for this Task was that most RUs used up-to-date GIS software to store their data, which facilitated the realization of a common platform for data sharing and knowledge transfer to future projects. Most of the results were funneled into the geodatabase realized by RU T.01. An added value in this Task is that several RUs supplied data that will outlast the work and interpretations done here (seeTable 5). This is a great though challenging opportunity, for it should stimulate collaborative efforts between and among different research groups and more foresighted and imaginative strategies in earthquake geology. To the knowledge of the task leader, this is the first time that such an opportunity came along in this kind of projects. Another opportunity was that many RUs provided insights about seismogenic structures, either newly discovered or already known, that will contribute in updating and enriching the seismogenic source model made available through the DISS (see map below). Several RUs have shown their interest in giving an effective contribution to this strategic development.

RU	National	Regional	Local
3.01	T		C
3.02			C
3.03			C
3.04			C
3.05			C
3.06	C/T	C	
3.07			C
3.08		C	C
3.09			C
3.10		C	C
3.11		C	C
3.12	T		
3.13	T		
3.14			C

Table 4: Scale of data collection/treatment by RUs; C: data collection; T: data treatment only.

Data type	**RU**
Instrumental age constraints on Late Pleistocene – Holocene deposits (ages obtained from Radiocarbon, OSL, U/Th methods)	3.01, 3.04, 3.07, 3.09
Active stress orientations from borehole breakouts: 64 new data; 41 of good quality	3.06
Seismic lines and other geophysical surveys (different scale)	3.05, 3.07, 3.08, 3.10, 3.11, 3.14
Database made available to the public (national scale)	3.12
Modeling at national scale	3.01, 3.13

Table 5: Summary of results obtained by RUs.

Progress of the task by RUs

This section summarizes the research activity carried out by each RU and their main achievements. Figure 20 should be used for a geographic reference of the area investigated. RUs 3.01, 3.12, and 3.13 are also carrying out work at the scale of the entire country.

RU3.01 (Basili) activity was multifaceted. They carried out extensive analysis about slip rate of seismogenic sources. Activities include review of methods used so far to estimate slip rates and their classification in terms of spatial and temporal scales. New estimates about model-derived slip rates were given. Two study cases augment the scientific significance of this activity. In the key area of Crotone peninsula (Calabrian Arc), new geologic and instrumental (A-InSAR) data were used to constrain tectonic rates (Figure 21). The Dinarides contractional belt was extensively analyzed, including field studies, to provide an updated version of seismogenic sources to be included in the DISS. A set of tests to validate the seismic source model of the DISS were designed, thereby providing a logical framework to address the seismogenic source model tectonic reliability. The uncertainties associated with earthquake occurrence probability were also addressed through a number of probability maps under different recurrence models and slip rate datasets.

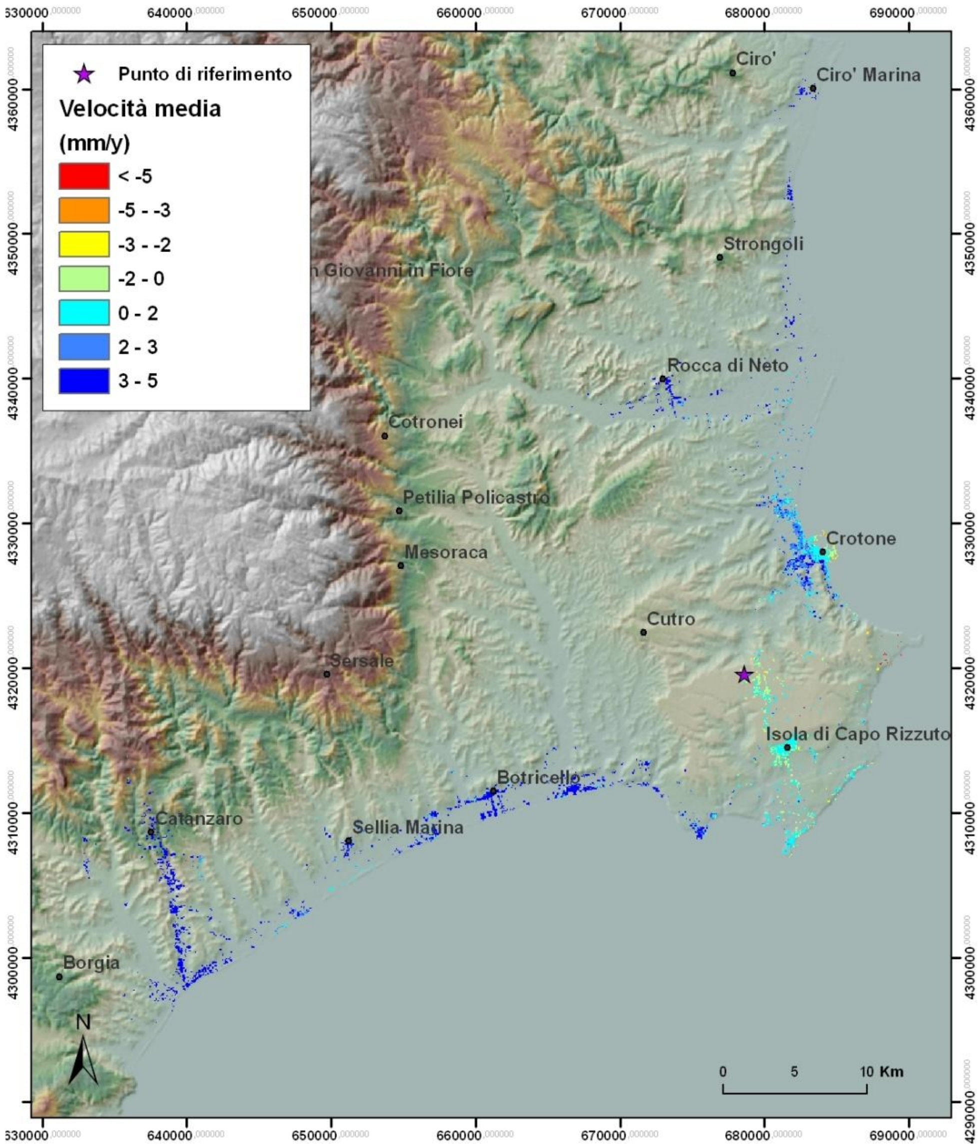


Figure 21: LOS velocity map along ascending path. The reference point is nearby Isola di Capo Rizzuto village.

RU3.02 (Catalano) is progressing in collecting original geomorphic and structural data in a sector of northeastern Sicily. Most significantly, they mapped a number of marine terraces and through correlation with sea level highstands determined local uplift rates. This analysis shows different uplift patterns on the two analyzed stretches of coast (about 100 km long each) of the island. On the basis of offset geological features and surficial geomorphic processes that may have misleadingly rejuvenated older geological structures, they group faults in age classes, namely Lower Peistocene, Middle-Lower Pleistocene, and Middle-Late Pleistocene faults. Following this grouping criteria they conclude that the southern portion of the ITCS042 Composite Seismogenic Source of the DISS should be limited to the offshore area.

RU3.03 (Faccenna) collected geomorphic and structural data in southern Calabria and partly in northeastern Sicily. Geomorphic data mainly concern stream profiling and knickpoint mapping whereas structural data mainly concern fault slickenlines used in classical kinematic analysis. All these data were fed into a database along with literature data, thereby aiming at an integrated tectonic interpretation. This RU started the analysis and interpretation of a number of seismic lines, exploiting data from the SISTER99 campaign, in a rather poorly explored area in the Calabria western offshore.

RU3.04 (Ferranti) work focused on quantifying Holocene uplift/subsidence rates along the Tyrrhenian and Ionian coasts of Calabria and discriminating between the regional (deep-seated subduction related) and local (crustal faulting related) components. They compiled a database of Holocene rates with a total of 61 sites, 16 of which studied in this project. Most of the new uplift rates exceed 1 mm/y (Figure 22). They also updated a previous compilation of Pleistocene uplift rates. Uplift data analyzed in the Sibari plain were carefully discriminated from local, compaction-induced, subsidence.

Figure 22: Holocene vertical displacement rates at the coasts of the Calabrian arc.

Assuming that sequences of raised shoreline can be generated by coseismic uplift, they identify four sectors of the Calabria coast where paleoearthquake could have occurred. Previously known sites

combined with two more sites studied during this project yield a total of 10 paleoearthquakes in the last 5 ky, three of which correlated with historical events.
Combining the analysis of raised Pleistocene terraces with geological structures mapping they propose five seismogenic shallow sources (5-7 km), capable of generating earthquakes up to Mw 6, in northeastern Calabria.

RU3.05 (Galadini) carried out a new geologic survey at the scale of 1:10000 in selected sectors of the area between the Lake Iseo and Verona. The main goals were to supply new stratigraphic data about the Alpine Cenozoic sedimentary succession and to verify the existence of neotectonic faulting. Interesting sites were object of detailed analytic studies, including sediment petrographic composition, pollen analysis, and paleomagnetism. Studied sites were the Monte Orfano (Lake Iseo), with Sale and Badia hills (Brescia), the Mt S.Bartolomeo (Salò), Calvagese, Sirmione, and S. Ambrogio Valpolicella. The area of Lake Garda was also explored in the subsurface through industrial seismic profiles and biostratigraphic analyses. New structural data and direct observations support a Pleistocene activity for the NW-SE S. Ambrogio fault, the existence of Middle Pleistocene faulting activity at Sirmione, and a Middle Pleistocene uplift of the western sector of the Lake Garda. Theses new findings are discussed and framed into a more regional structural model from the Berici-Euganei axis and the Adda River.

RU3.06 (Mariucci) main goal was measuring orientation of the maximum horizontal stress orientation in the crust. During the first year they analyzed 46 well caliper logs located in the southern Apennines. During the second year they analyzed 18 new well logs. Their geographic distribution spans from eastern Sicily (13), Adriatic offshore (4) and the Po Plain (1). Ten data sets have been evaluated as being useful for borehole breakout analysis and 9 reliable stress orientations were obtained. Results show a general extension with Shmin oriented in a NE-SW direction for the foredeep of the southern Apennines. Stress data along the Tyrrhenian coast are relevant as very few data existed before this analysis. Shmin orientations in this area are quite variable and seem to point out a general extension with a vertical σ1 and without a prevailing horizontal stress component. New borehole breakout data in Sicily confirm the NW-SE oriented compression direction in the Hyblean foreland and a 90° change in the orientations in the foredeep.

RU3.07 (Michetti) collected data at a very detailed scale in two sites: Monte Netto nearby Brescia and Borgo Vico in Como. Work in the Monte Netto site includes exploratory trenching, geophysical surveying, and geochronological analysis. These activities are meant to shed light on E-W trending back thrusts (south plunging) associated with the main South Alpine chain buried below the Po Plain post-glacial alluvial. One trench, Cava Danesi site, provided evidence for three paleoearthquakes occurred between 45 ky BP and 5 ky BP.
In the Lake Garda area, high resolution multi-beam bathymetric data were collected between San Vigilio Point and Sirmione Peninsula in order to recognize seismically-induced structures and deposits. Main preliminary results in interpreting data from this campaign suggest tha a number of fault line could be mapped and correlated with structures on land thereby providing new evidence of Quaternary faulting in this area.
A database of seismic-induced environmental effects due to earthquakes in the Garda Lake area was also compiled.

RU3.08 (Polonia) main goal was to study and characterize the potential seismogenic structures located close to the coast and the offshore of the Italian peninsula. Three regions were studied: the offshore to the north and east of the Gargano promontory, the offshore to the south of the Gargano promontory, and the Calabrian Arc accretionary prism (Ionian Sea).
Results of studies carried out in the off-shore of the Adriatic Sea, north of the Gargano Promontory, based on interpretation of seismic profiles suggest the presence of a shallow (5-7 km), NE-SW

trending, active contractional belt (Tremiti line). On this basis, the previously proposed activity on deep (11-25 km) E-W trending, right-lateral strike-slip faults, is deemed not to occur.

Results of high-resolution seismic stratigraphy in the Adriatic Sea, south of the Gargano Promontory, yield evidence of activity younger than 5.5 ka along the entire length of the Gondola Fault Zone (GFZ). Detailed studies of the WNW-ESE portion of the GFZ were added during this project. Results indicate that in part of the fault zone, evidence of shallow faulting in recent sediments is less continuous than thought, which can be attributed to the different activity of the GFZ along its whole trace and the role of sediment deposition/remobilization and erosion by high energy processes typical of the deeper slope environment. Nonetheless, this part of the fault zone as-well exhibits recent displacements that correspond to dip-slip movements along WSW dipping fault planes. Along the entire length of the fault system pre-existing structures, and thus reactivation processes, play an important role.

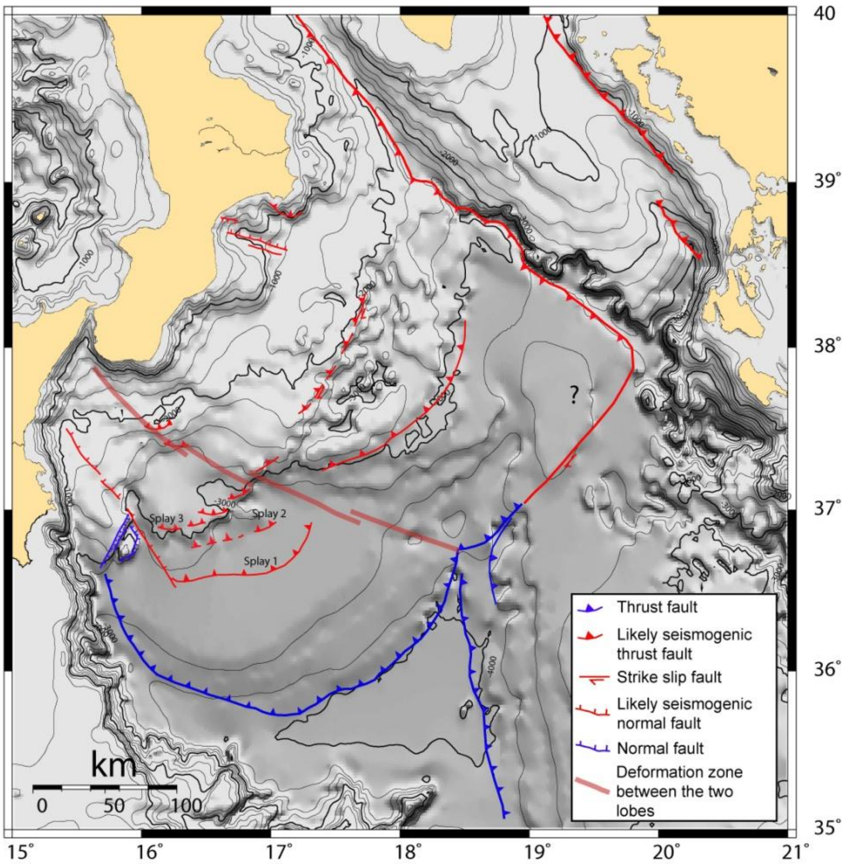


Figure 23: Structural map derived from the interpretation of the available seismic data. The outer deformation front and major structures are evidenced. The continental margin appears to be segmented both across and along strike. In particular, two lobes of the accretionary wedge are separated by a curvilinear structural boundary possibly accommodating different rates of shortening and slab dynamics.

Important results were obtained for the structure of the Ionian subduction, its accretionary prism and possible seismogenic character of the thrust faults within the accretionaty complex that were not mapped before this project (Figure 23). Results show the presence of two distinct accretionary prism bodies corresponding to the pre- and post-Messinian stages of the subduction with the basal detachment in the outer portion running along the base of the Messinian evaporites body with a shallow angle of 4°, whereas in the inner sector the basal detachment becomes steeper and deeper and seems to involve basement rocks. Within the accretionary body four active thrust faults (three belonging to the outer and one to the inner portion of the accretionary prism) that accommodate the plate motion were identified. This evidence confirms the present activity of the subduction, although it does not allow to ultimately considering the Ionian subduction zone as aseismically active or locked.

RU3.09 (Pucci) mainly focuses on two areas: Belice (Sicily) and the central Apennines.
As for the first area, they put together existing geological data and collected new data from aerial photo interpretation, standard geomorphic analysis, and field survey. The main product of this study is a new geological/geomorphic map of the area which illustrates the internal stratigraphy of the marine Pleistocene sequence. Preliminary uplift rate were estimated at 0.55 mm/y, however, dating of terraces, still in progress, should help discriminate regional uplift from local warping due to active structures at local scale.
As for the second area, they compared Bouguer anomalies and seismicity depth distribution along the CROP03 and CROP11 profiles.
They also prepared a mapped the seismicity cut-off in Italy.

RU3.10 (Scrocca) acquired seismic reflection profiles, well logs, geological field observations, and geological literature data, about a large area stretching from the Po Plain to the Adriatic Sea, both onshore and offshore, all along the northern and central Apennines. The main goal was to improve the geometric and kinematic definition of active tectonic structures, mainly thrusts, at seismogenic depth.
The study of coastal and offshore areas of Abruzzo and Marche confirmed the recent activity of crustal thrust faults (Figure 24).
An important result is represented by the structural maps in the central Adriatic off-shore that depict the location of individual thrust fault planes. They give evidence for late Quaternary contractional deformation affecting the off-shore innermost thrust plane (Graziella Mare-Conero structure). Fault activity seems to decrease towards the external sector of the chain where, the identified several structures of the thrust system (Clara, Colosseo and Cornelia-Elga trends) do not show evidence of deformation in the middle-late Pleistocene. These structures have been deformed during an early forward propagation of the thrust along an efficient detachment which was followed by a shift of the tectonic activity towards inner portions of the wedge. These results provide insights into ITIS029 and ITCS008 seismogenic sources of the DISS.
In the Abruzzo onshore area they provided further geometric and kinematic constraints on already identified active thrust structures and additional insights into several seismogenic sources.
Newly obtained seismic data in the Po Plain, together with existing geological and seismicity data, provided a 3D reconstruction of the basal detachment of the Northern Apennines accretionary prism. This reconstruction opens new questions about deep-focus seismicity in the area.

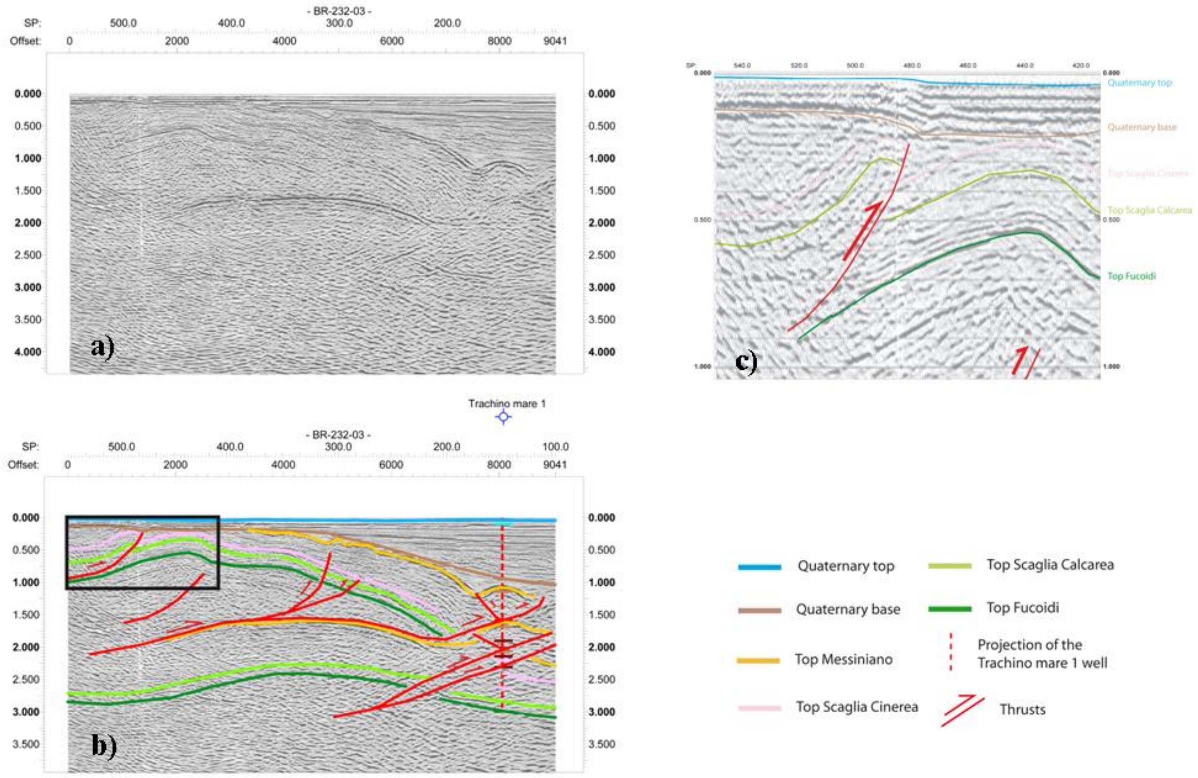


Figure 24: Seismic reflection profile BR-232-03 (see report of RU 3.10 for details): a) uninterpretd, b) interpreted, and c) detail showing the deformation of the Quaternary sedimentary unit due to thrust activity.

RU3.11 (Seno) collected data about contractional tectonic structures buried below the central Po Plain alluvial deposits. Data concern geological cross section, Plio-Pleistocene aquifers, seismic profiles, and geomorphic analyses. Analog models were also set up to constrain the tectonic behavior of multiple thrusts under various boundary conditions.

Main results include: a detailed description of the structural setting of the Central Po Plain and the kinematic events studied through analogue models and a description of how deformation is distributed on different structures within a regional structure; morphotectonic analysis of the Emilian arc, Ferrara arc and Central Po Plain; new insights about an already seismogenic structure (Ferrara 1570) and new hypothesis on the seissmogenic sources of the 1909 and 1796 earthquakes; structural analysis of the buried structures under the Central Po Plain with a quantitative analysis of the recent kinematics of two opposite verging chains.

RU3.12 (Vannoli) main goal was to increase and update the content of the Database of Individual Seismogenic Sources (DISS,Figure 25), and to improve its structure and functionalities for the benefit of its users. The documentation about the seismogenic sources based on geological/geophysical data was significantly increased. Each record of the database now has a “commentary” and a number of figures. References to scientific papers have also increased to over 2600, so that only a minimal number of records show less than 10 citations.

Areas with significant review of seismogenic sources are the Lombardia/Veneto, and the Abruzzo/Molise. New data about the Dinarides were also incorporated. Several of these updates come from contributions of other research units of the project (e.g. 3.01, 3.07, 3.08, 3.10, and 4.01). The layer of Debated Seismogenic Sources have also been remarkably extended (26 new records) and improved.

Support to other RUs of the project in the use of the database was also warranted through dedicated data extraction and customization. The graphic user interface was improved.

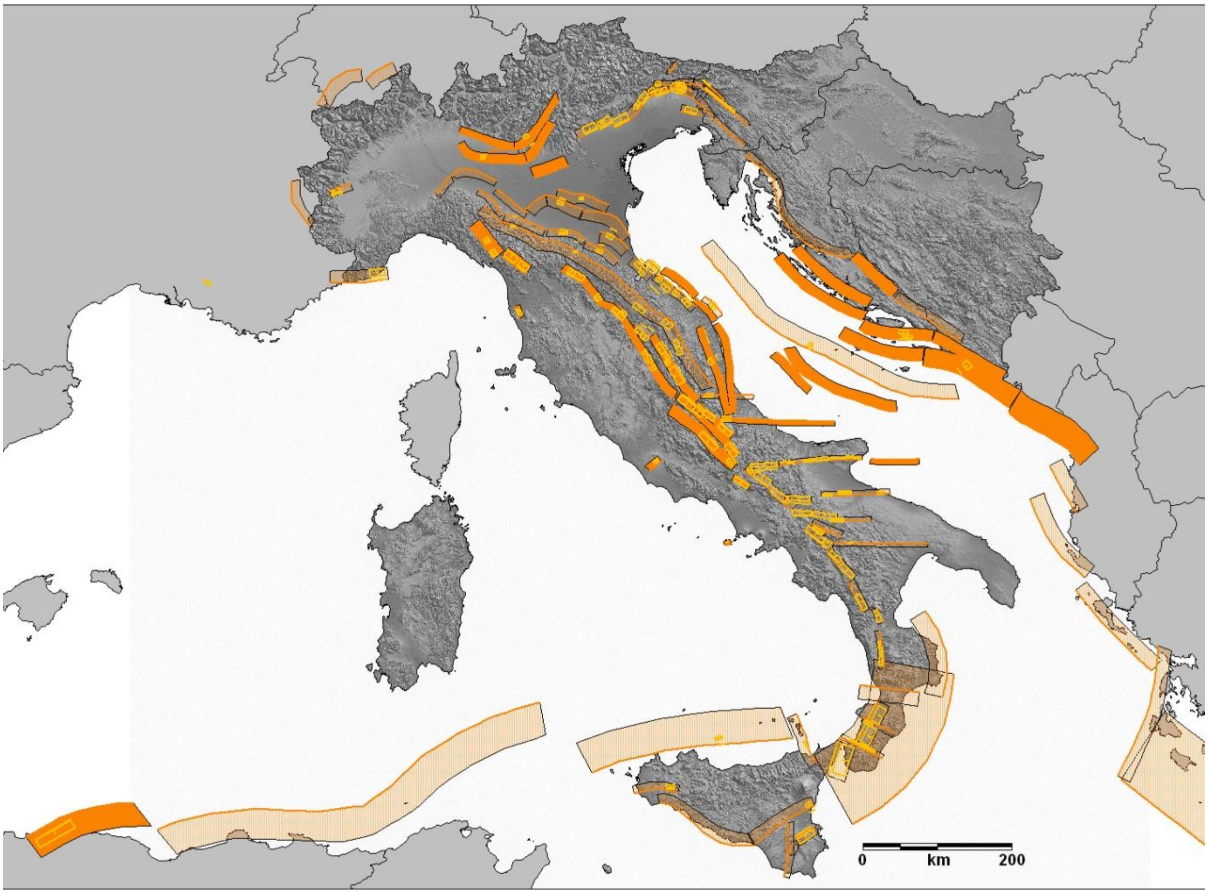


Figure 25: Individual Seismogenic Sources in yellow and Composite Seismogenic Sources in orange. Dark orange marks the new/modified Composite Seismogenic Sources.

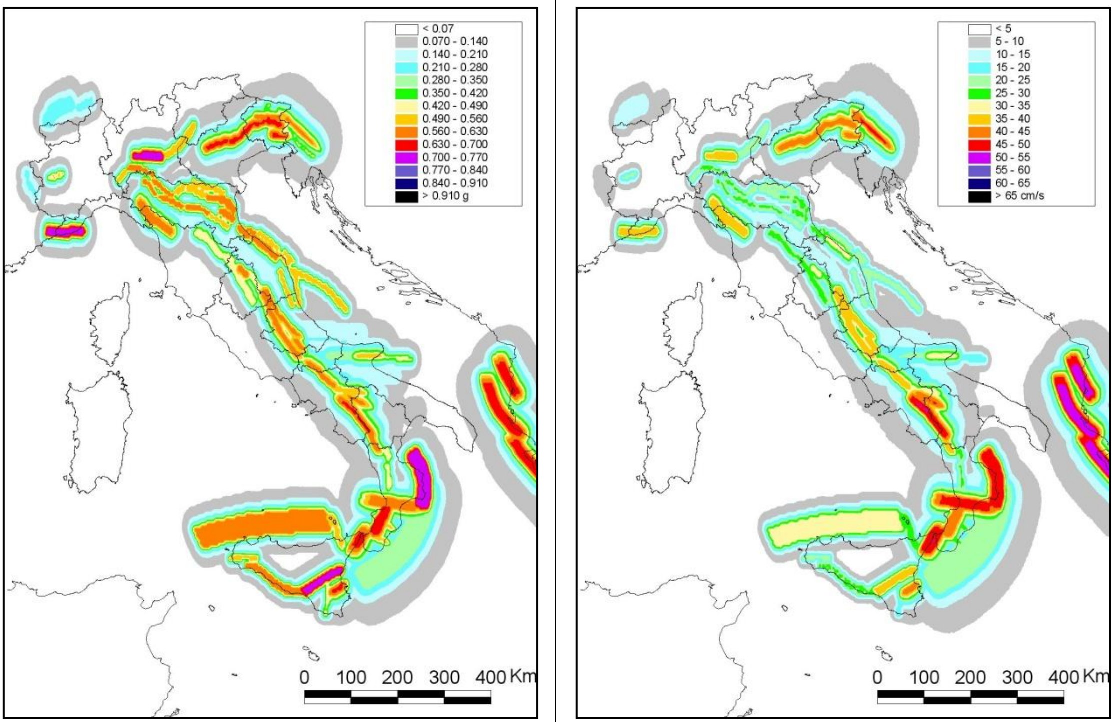
RU3.13 (Zonno) main goal was to establish a work flow for a multi-layer map that includes the seismicity of Italy in terms of Maximum Observable Shaking (MOS), and the near-field/far-field boundaries (NF/FF) with respect of the major seismogenic faults.

A set of MOS maps for the entire Italian territory was completed in the high-frequency domain (Figure 26). They are expressed in terms of the ground-motion parameters of PGA (cm/s^2), PGV (cm/s), SI-HI (cm) and SD (cm), and allow an evaluation of the potential impact of expected earthquakes. Several tests against independent data and sensitivity tests at local and national scale support the feasibility of the results.

A working framework about how potentially derive empirical relations that may allow delineating NF/FF boundaries was designed. If such a boundary can indeed be quantified, even if only approximately, one can choose to simulate ground-shaking for a given type of building or infrastructure, according to whether its location occurs in the NF or FF regime, with respect to a given source, and for a given frequency of interest.

RU3.14 (Solarino) has compiled a database of seismic location with improved location error in the Ligurian Sea. The results were basically achieved through deployment of OBS instruments which significantly decreased the azimuthal gap. The additional phase pickings from stations at sea and the application of tomographic methods also provided an accurate mapping of seismic velocities and Vp/Vs anomalies. Five focal mechanisms, three of which located offshore, were also calculated with great accuracy thank to the high number of phase readings. Collectively they show predominant NW-SE trending P axes.

HF MOS map in terms of PGA	HF MOS map in terms of PGV



HF MOS map in terms of SI (Housner)	HF MOS map in terms of SD_{10sec}

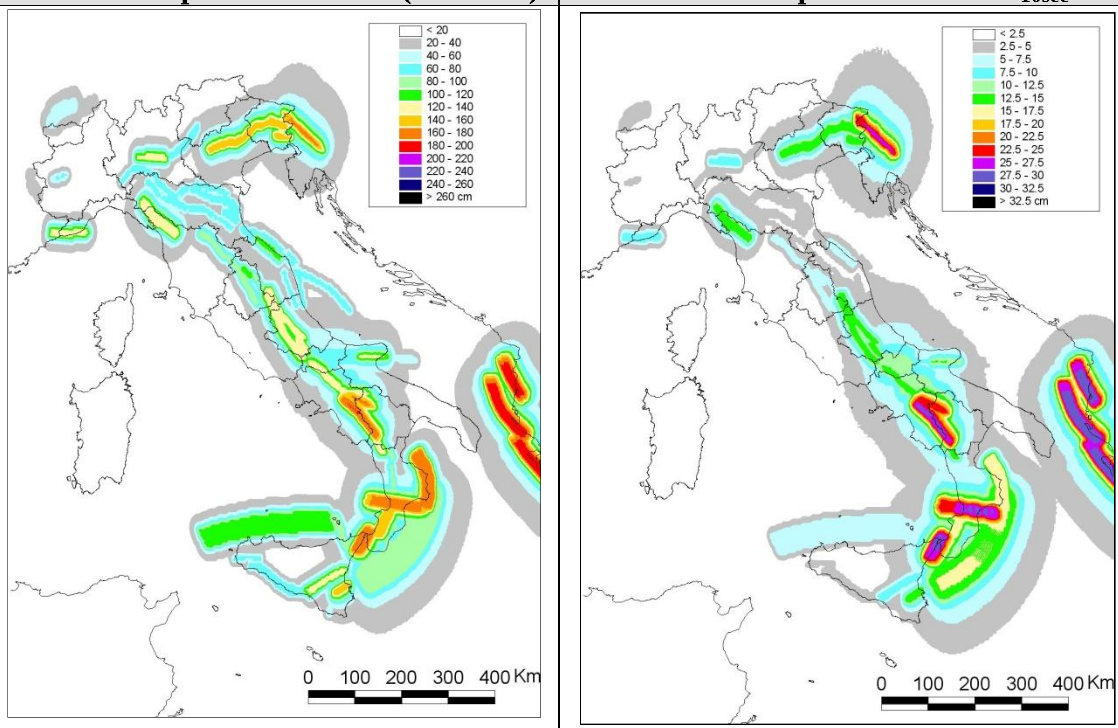


Figure 26: HF MOS maps in terms of PGA (g), PGV (cm/sec), SI-HI (cm) and SD10sec (cm) using the Gaussian slip distribution.

Deliverables

The Table below summarizes the status of completion of deliverables. For several RUs it was not possible to clearly understand or estimate the amount of completion. One RU is totally missing (Deliverables are marked in gray shade in the table). Some Deliverables (marked with strikethrough line) have been canceled, modified, or incorporated into others for simplicity.

RU	RU responsible	Deliv. #	Status %	DPC	Deliverable
3.01	Basili R.	D3.01.1	100	pp	Technical report illustrating the results obtained in the Crotone Peninsula based on geological and InSAR data. Geological: map of coastal and fluvial terraces; map of long-term (100 ky) vertical movements. InSAR: ground velocity maps measured along both ascending and descending satellite orbits; vertical component of the ground velocity; East-West ground velocity map.
		D3.01.2	100	Y	Slip rate data on seismogenic sources included in DISS
		D3.01.3	100	N	Parameters of seismogenic sources in the key areas studied by RU 3.01 (contributing to populate DISS)
		D3.01.4	100	Y	Probability of occurrence for earthquakes generated by individual faults and the associated uncertainties
		D3.01.5	100	N	Results of tectonic validation for the seismogenic source model (DISS).
3.02	Catalano S.	D3.02.1	100	Y	1:25.000 scale morphotectonic map of the NE Sicily, from Capo Calavà to Milazzo and the 1:10.000 scale morphotectonic maps of Lipari and the eastern coast of Salina
		D3.02.2	100		Shape-file of the entire dataset of mapped faults
		D3.02.3	100		Digital map of structural measurement stations and related stereoplots
		D3.02.4	100		Tables on the elevation and inferred age of the Late Quaternary marine terraces
		~~D3.02.5~~	~~0~~		~~Mid-term papers or short-notes~~
		~~D3.02.6~~	~~0~~		~~final report to be published on international journal~~
3.03	Faccenna C.	D3.03.1	100		GIS map of active faults and associated main earthquakes (Tyrrhenian side, Calabria)
		D3.03.2	100	Y	Maps of active faults of Tyrrhenian side, Calabria (Include morphotectonic maps, cross-section, kinematic analysis)
		D3.03.3	10	Y	Maps of recent faulting on the Tyrrhenian margin
		D3.03.4	100		Maps of seismicity (include: non linear distribution of earthquake, hypocentral cross-section, density distribution), Tyrrhenian side, Calabria.
3.04	Ferranti L.	D3.04.1	100		Holocene vertical crustal displacement rates for selected sectors of Sicily/Calabria (preliminar) (delivered on 1st year; final version see D3.04.5)
		D3.04.2	100	Y	Computation of regional vs. co-seismic component of displacement for selected sectors of Sicily/Calabria
		~~D3.04.3~~		~~Y~~	~~Pleistocene vertical displacement rates for selected sectors of Sicily/Calabria~~ (joined with D3.04.5)
		D3.04.3	100	Y	Parameters of active structures (sea-land) for selected sectors of Sicily/Calabria
		D3.04.5	100	Y	Holocene vertical crustal displacement rates for selected sectors of Sicily/Calabria (final)
3.05	Galadini F.	D3.05.1	100	Y	Evaluation of the Quaternary tectonic activity in the area between the Adda River and the Berici-Euganei axis
		~~D3.05.1~~			~~Geological and structural map of the studied sector of the South-Alpine front between the Euganei-Berici axis and the Adda River~~
		~~D3.05.2~~			~~Report containing the localization and the definition of the geometrical and kinematic characteristics of tectonic structures active during the Quaternary~~
		~~D3.05.3~~		~~Y~~	~~Map of the possible seismogenetic sources of the of the South-Alpine front between the Euganei-Berici axis and the Adda River~~
		~~D3.05.4~~			~~Report containing the result of the re-localization of the instrumental seismicity data.~~
		~~D3.05.5~~			~~Maps of the seismic energy released in the investigated sector of the Northern Italy.~~
3.06	Mariucci M.T.	D3.06.1	100	Y	Table with breakout analysis results
		D3.06.2	100		Active stress map of Italy updated to 2008
		~~D3.06.3~~	~~0~~		~~Smoothed stress maps of Italy~~
3.07	Michetti A.M.	D3.07.1	100	Y	Log of the excavated walls at the Monte Netto site, Brescia (Lombardia) in a scale of detail (up to 1:20) including AMS and OSL dating. (delivered in 1st year)
		D3.07.2	100	Y	Structural interpretation of the Monte Netto anticline and relationships with the causative backthrust. Assessments of the Late Quaternary slip rate of the Monte Netto anticline and modeling of the basal backthrust. (delivered in 1st year)
		D3.07.3	100	Y	GPR survey and geoelectric tomography in the Monte Netto area. (delivered in 1st year)
		D3.07.4	100	Y	High resolution, shallow seismic reflection profiles in the Lake garda offshore
		D3.07.5	100	Y	Compilation and analysis of the coseismic environmental effects triggered by historical earthquakes in the Lombardia Po Plain and surrounding regions.
		~~D3.07.6~~		~~Y~~	~~Calibration of the deformation rates of capable tectonic structure mapped along the Lombardia Southern Alps and adjoining Po Plain.~~ (substituted with D3.07.10)
		D3.07.7	100	Y	Regional mapping of the active compressional structures identified and assessment of the source parameters for seismic hazard assessment. (delivered in 1st year)
		D3.07.8	100		Building and management of a web page for the progressive illustration of the project results.
		D3.07.9	100		Scientific papers to be published on journals with impact factor. (delivered in 1st year)

		D3.07.10	100	Y	Geomorphic investigation, field mapping and ENI seismic reflection data modeling along other Quaternary structure in the Lombardia Southern Alps (not planned)
3.08a	Argnani A.	D3.08.1	100	Y	Tectonic map of the peri-gargano region with the active structures highlighted (within report)
		D3.08.2	100	Y	Characterization of the active tectonic structures of the peri-Gargano region and their relationship with sesmicity. (within report)
		D3.08.3	100		Proposal of a deformation model for the peri-Gargano region (within report)
3.08b	Trincardi F.	D3.08.4	100		3D bathy-morphological reconstruction of the apulian slope and definition of the deformation pattern at the sea floor along Gondola fault (within report and geodatabase)
		D3.08.5	100	Y	Precise dating of the sedimentare units affected by the various segments of Gondola deformation belt; (within report and geodatabase)
		D3.08.6	100		Proposal of a deformation model for Gondola deformation belt during the late Quaternary (within report and geodatabase)
3.08c	Polonia A.	D3.08.7	100	Y	Line drawing of pre stack depth migrated seismic line CROP M-2B (within report)
		D3.08.8	100	Y	Line drawing of Sparker seismic line J-08 (within report)
		D3.08.9	100		Structural map of the Calabrian Arc in the Ionian Sea (within report and geodatabase)
3.09	Pucci S.	D3.09.1	100		Geological-Geomorphological map (scale 1:50.000) (western Sicily)
		D3.09.2	100		Map of the Quaternary deposits and landforms of the key areas (scale 1:10.000 or 1:5.000) (western Sicily)
		D3.09.3	100	Y	Structural maps of the key areas (scale 1:10.000 or 1:5.000) (western Sicily)
		D3.09.4	100		Geo-structural and morphological profiles of the key areas (scale 1:10.000 or 1:5.000) (western Sicily)
		D3.09.5	100		Various geo-statistical thematic maps (slope, drainage evolution, hydrologic sub-basins analysis, morphometric derivatives of digital terrain models, ecc.) (western Sicily)
		D3.09.6	100		Map of the palinspastic reconstruction of the Pleistocene and Holocene landforms of the key areas (scale 1:10.000 or 1:5.000) (western Sicily)
		D3.09.7	100		Schematic conceptual model of the estimate of the Quaternary deformations (western Sicily)
		D3.09.8	100	Y	Graphs of rates and values of the deformation and its distribution (western Sicily)
		D3.09.9	100		Seismicity Cut-off of the Italian region
		~~D3.09.9~~	~~0~~		~~Reconstruction of main seismic horizons on the the central part of the CROP03 - Umbria-Marche Apennines- and CROP11 -Lazio-Abruzzo Apennines- regional seismic reflection profiles~~
		~~D3.09.10~~	~~0~~		~~Map of seismicity and Bouguer anomalies of the area included between the two regional seismic reflection profiles (CROP03 and CROP11)~~
		~~D3.09.11~~	~~0~~	~~Y~~	~~Depth of the B/D transition in the area included between the two seismic transects (CROP03 and CROP11)~~
3.10	Scrocca D.	D3.10.1	100		Geometry of the basal detachment surface of the Northern Apennines accretionary prism beneath the Po Plain
		D3.10.2	100	Y	Improved definition of the geometry at depth of the "ITSA050 - Poggio Rusco-Migliarino", "ITSA051 - Novi-Poggio Renatico", "ITGG107 – Mirandola" sources
		D3.10.3	100		Representative transects across the central-northern sectors of the Apennines analysing relationships between shallow and the deeper seismicity
		D3.10.4	100	Y	Main geometric parameters for the "ITSA054 - Southern Marche offshore" and "ITSA052 - Mid-Adriatic offshore" sources
		D3.10.5	100	Y	Characterization of the seismogenic area "ITSA020 - Southern Marche"
3.11	Seno S.	D3.11.1	100	Y	Geological cross sections through the Po Plain (georeferenced and in a format suitable for importing in common GIS and database programs)
		D3.11.2	100	Y	Geometries and depth of fault planes and decollement levels (in 2 geological cross sections trough the Po Plain)
		D3.11.3	100	Y	Morphotectonic map (fluvial terraces and hydrographic network anomalies) of the southeastern Po Plain (Romagna area)
		~~D3.11.4~~		~~Y~~	~~Quantification of selected seismotectonic parameters (geometric and kinematics) of Quaternary blind faults within the Romagna area~~
		D3.11.5	100	Y	GIS based representation of subsurface faults data coupled with geo-morphological evidences of present activity in the central Po Plain.
		D3.11.6	100	Y	Updating the DISS database in the central Po Plain (Apennine and Southern Alps fronts)
3.12	Vannoli P.	D3.12.1	100	Y	A new version of DISS cointaining the scientific and technological updates stemming from the Project
3.13	Zonno G.	D3.13.1	100	Y	Maximum Observable Shaking (MOS) maps of Italy in terms of PGA (cm/sec2) and SI-Housner (cm) but also in PGV (cm/sec) and SD (cm)
		~~D3.13.1~~	~~100~~	~~Y~~	~~PGA map of Italy using individual sources of DISS~~ (changed with new D3.13.2)
		~~D3.13.2~~	~~100~~	~~Y~~	~~SI (Housner) map of Italy using individual sources of DISS~~ (changed with new D3.13.3)
		~~D3.13.3~~	~~100~~	~~Y~~	~~PGA map of Italy using individual and area sources of DISS~~ (changed with new D3.13.2)
		~~D3.13.4~~	~~100~~	~~Y~~	~~SI (Housner) map of Italy using individual and area sources of DISS~~ (changed with new D3.13.3)
		D3.13.2	100	Y	Delimitation of Near-fields boundaries

		D3.13.3	100	Y	High-Frequency Maximum Observable Shaking Map of Italy from Fault Sources
3.14	Solarino S.	D3.14.1	100		Table of earthquake data (phase readings) recorded during the OBS and land campaign in the Ligurian Sea
		D3.14.2	100	Y	Table of earthquake locations recorded during the OBS campaign in the Ligurian Sea
		D3.14.3	100		1-D and 3-D tomographic models of Ligurian Sea
		D3.14.4	100		Table of fault plane solutions

Management

This task was composed of 14 RUs, which is a large number by itself, some of which with goals and approaches very different from all others. For this reason the steering committee agreed not to organize meetings at the task level. Project meetings were held in Rome where almost all RUs gathered and had an opportunity to compare their strategies, objectives, and achievements. In these occasions, collaboration within the task was stimulated by recommending interactions between and among RUs, especially for those RUs that were carrying out research in overlapping or conterminous regions. In the first year of the project all RUs were strictly focused on acquiring new data, therefore the interaction was minimal. In the second year there have been meetings of small groups to share experiences and views. A series of seminars were organized at INGV for some of the RUs working in the offshore because of the peculiarity of their activity with respect to the Project.

Some of the RUs established an effective common platform. T01 and T02 were very effective in continually engaging most RUs of this task. RU3.12 is probably the one that better interacted with most other RUs in both directions of exchange (receiving data from RU 3.01, 3.07, 3.08, 3.10, and 4.01; providing data to RU 3.01, 3.13, S.02, S.03, T.02, and Project S2). Other collaborations were sought between and among several other RUs. Given the peculiarity of their activity, for some RUs (e.g. RU 3.14 and 3.06) collaboration was neither easy nor much needed.

Problems and difficulties

This section summarizes the main issues of the Task. In general, only few problems arose within RUs that required changes in the planned activities. These can be seen in RUs reports. Most of the modification of the original plans can be considered to be within the usual range of unpredictability of research work. The task itself did not required major changes. RU3.13 was rather isolated because its goal was basically to model data rather than collecting data which was the main purpose of this Task. Also, RU3.06 was rather isolated because the type of collected data is very peculiar.

Main key publications

Key publication list by RU include paper published, in press, or submitted to journals and websites. Conference abstracts (present and future) and papers published in 2008 were not considered.

3.01
None.

3.02
None.

3.03
Billi, A., Presti, D., Orecchio, B., Faccenna, C. and Neri G. (2010), Incipient extension along the active convergent margin of Nubia in Sicily, Italy: the Cefalu-Etna seismic zone, Tectonics, doi:10.1029/2009TC002559, in press.

Minelli, L., and Faccenna, C. (2010), Evolution of the Calabrian accretionary wedge, central Mediterranean, Tectonics, doi:10.1029/2009TC002562, in press.

Olivetti, V., M. L. Balestrieri, C. Faccenna, F. M. Stuart, and G. Vignaroli (2010), MiddleMiocene out-of-sequence thrusting and successive exhumation in the Peloritani Mountains, Sicily: Late stage evolution of an orogen unraveled by apatite fission track and (U-Th)/He thermochronometry,Tectonics, doi:10.1029/2009TC002659, in press.

Faccenna, C., Molin, P., Orecchio, B., Becker, T.W., Bellier, O., Funiciello, F., Minelli, L., Neri, G., Olivetti, V., Piromallo, C., Billi, A., (2008). Topography of the Calabria subduction zones. Tectonics, submitted.

3.04

Antonioli, F., Ferranti, L., Fontana, A. , Amorosi, A.M., Bondesan, A, Braitenberg, C., Dutton, A., Fontolan, G., Furlani, S., Lambeck,, K., Mastronuzzi, G, Monaco, C., Spada, G. , Stocchi, P., 2009. Holocene relative sea-level changes and vertical movements along the Italian and Istrian coastlines. Quat. Int., 206: 102-133, doi:10.1016/j.quaint.2008.11.008.

Ferranti, L., Antonioli, F., Monaco, C., 2008. The contribution of deep and shallow sources to uplift of the Calabrian arc at different timescales. Rend. online Soc. Geol. It., 1, 83-85.

Ferranti, L, Antonioli, F., Anzidei, M., Monaco, C., Stocchi, P. - The timescale and spatial extent of vertical tectonic motions in Italy: insights from relative sea-level changes studies. Journal of the Virtual Explorer, Special Issue: The Geology of Italy, in press.

Ferranti, L., Mazzella, M. E., Monaco, C., Morelli, D., Santoro, E., 2009. Active transpression within the frontal zone of the Southern Apennines in northern Calabria by integration of geomorphologic, structural, and marine geophysical data. Rend. online Soc. Geol. It., 5, 97-99.

Ferranti, L, Pagliarulo, R., Antonioli, F., Randisi, A. - Relative sea level changes and differential tectonic motion at the ancient Sybaris (Calabria, southern Italy). In: Tectonic contribution to relative sea level change (edited by F. Antonioli, S. Faivre, L. Ferranti, C. Monaco), Quat. Int., Special Issue, in press.

Ferranti, L., Santoro, E. Mazzella, E., Monaco, C., Morelli, D., 2009. Active transpression in the northern Calabria Apennines, Southern Italy. Tectonophysics, 476: 226–251 doi:10.1016/j.tecto.2008.11.010.

Lambeck , K., Antonioli, F., Anzidei, M., Ferranti, L., Leoni, G., Scicchitano, G. - Sea level change along the Italian coast during the holocene and projections for the future. In: Tectonic contribution to relative sea level change (edited by F. Antonioli, S. Faivre, L. Ferranti, C. Monaco), Quat. Int., Special Issue, in press.

Santoro, E., Mazzella, E., Ferranti, L., Randisi, E., Napolitano, E., Rittner, S. & Radtke U., 2009. Raised coastal terraces along the Ionian Sea coast of northern Calabria, Italy, suggest space and time variability of tectonic uplift rates. Quat. Int., 206: 78-101, doi:10.1016/j.quaint.2008.10.003.

Scicchitano, G., Lo Presti, V., Spampinato, C. R., Morticelli, M. G., Antonioli, F., Auriemma, R., Ferranti, L., Monaco, C. - Millstones as indicators of relative sea level changes in northern Sicily and southern Calabria coastlines. In: Tectonic contribution to relative sea level change (edited by F. Antonioli, S. Faivre, L. Ferranti, C. Monaco), Quat. Int., Special Issue, in press.

Scicchitano, G., Spampinato, C. R., Ferranti, L., Antonioli, F., Monaco, C., Capano, M., Lubritto, C. - Uplifted Holocene shorelines at Capo Milazzo (NE Sicily, Italy): evidence of co-seismic and steady-state deformation. In: Tectonic contribution to relative sea level change (edited by F. Antonioli, S. Faivre, L. Ferranti, C. Monaco), Quat. Int., Special Issue, in press.

3.05

Sciunnach, D., Scardia, G., Tremolada, F., Premoli Silva, I., in press. The Monte Orfano Conglomerate revisited: stratigraphic constraints on Cenozoic uplift of the Southern Alps (Lombardy, Northern Italy). International Journal of Earth Science, DOI 10.1007/s00531-009-0452-2, on-line 29 May 2009.

3.06
Barba S., Carafa M.M.C., Mariucci M.T., Montone P., Pierdominici S., 2010. Present-day stress-field modelling of southern Italy constrained by stress and GPS data. Tectonophysics, 482(1-4), 193–204, doi:10.1016/j.tecto.2009.10.017.

3.07
Livio F.A., Berlusconi A., Michetti A.M., Sileo G., Zerboni A., Trombino L., Cremaschi M., Mueller K., Vittori E., Carcano C., Rogledi S., 2009. Active fault-related folding in the epicentral area of the December 25, 1222 (Io = IX MCS) Brescia earthquake (Northern Italy): seismotectonic implications. Tectonophysics – Vol. 476, Issues 1-2, pp. 320-335.

3.08
Argnani A., Rovere M. and Bonazzi C., 2009. Tectonics of the Mattinata Fault offshore south Gargano (southern Adriatic Sea, Italy): implications on active deformation in the foreland of the Southern Apennines. G.S.A. Bull., 121: 1421-1440.

Di Bucci, D., Ridente, D., Fracassi, U., Trincardi, F., Valensise G., 2009. Marine paleoseismology from Very High Resolution seismic imaging: the Gondola Fault Zone (Adriatic foreland). Terra Nova, 21: 393-400.

Polonia A., Torelli L., Gasperini L., Riminucci F., Mussoni P., Gallais F., Gutscher M.-A., Artoni A., and Klaeschen D. The Calabrian Arc subduction complex in the Ionian sea: regional architecture, active deformation and seismic hazard. Submitted to Tectonics.

3.09
None.

3.10
Carminati, E., Scrocca, D., Doglioni, C., 2010. Compaction-induced stress variations with depth in an active anticline: Northern Apennines, Italy. Journal of Geophysical Research, 115, B02401, DOI:10.1029/2009JB006395.

Cuffaro, M., Riguzzi, F., Scrocca, D., Antonioli, F., Carminati, E., Livani, M., Carlo Doglioni, 2010. On the geodynamics of the northern Adriatic plate, Rendiconti Accademia Lincei, (submitted).

3.11
Toscani, G., Burrato, P., Di Bucci, D., Seno, S. & Valensise, G. 2009. Plio-Quaternary tectonic evolution of the Northern Apennine thrust front (Bologna-Ferrara section, Italy): seismotectonic implications. Italian Journal of Geosciences, vol. 128 n°2, 605-613. doi 10.3301/IJG.2009.128.2.605

Toscani, G., Burrato, P., Di Bucci, D., Ahmad, I., Seno, S., Valensise, G. 2010. Active thrusting underneath the Po Plain (Bologna-Ferrara section, Italy): insights from analogue modeling. Submitted to Terranova

3.12
Basili, R., Kastelic, V., Valensise, G., DISS Working Group, 2009. DISS3 tutorial series: Guidelines for compiling records of the Database of Individual Seismogenic Sources, version 3. Rapporti Tecnici INGV, 108: 20 p. http://portale.ingv.it/produzione-scientifica/rapporti-tecnici-ingv/archivio/rapporti-tecnici-2009/

Di Bucci, D., Burrato, P., Vannoli, P., Fracassi, U., Valensise, G., *submitted*. Seismogenic faults and their surface signature: insights from the 2009 L'Aquila earthquake (Central Apennines, Mw 6.3) for the understanding of adjacent areas. Terra Nova.

Di Bucci, D., Ridente, D., Fracassi, U., Trincardi, F., Valensise, G., 2010. Marine paleoseismology from Very High Resolution seismic imaging: the Gondola Fault Zone (Adriatic foreland). Terra Nova, 21: 393-400. doi: 10.1111/j.1365-3121.2009.00895.x.

websites
DISS Working Group 2009 (Barba, S., Basili, R., Burrato, P., Fracassi, U., Kastelic, V., Tiberti, M.M., Valensise, G., Vannoli, P.), 2009. Database of Individual Seismogenic Sources (DISS), Version 3.1.0: A compilation of potential sources for earthquakes larger than M 5.5 in Italy and surrounding areas. http://diss.rm.ingv.it/diss/, June 2009.

3.13
None.

3.14
Dessa, J.X., Béthoux, N., Beslier, M.O., Hello, Y., Anglade, A., Desprez, O., Ruiz Fernandez, M., Manchuel, K., Verdier, E., Deschamps, A., Courboulex, F., Brunel, D., Klingelhoefer, F., Bellier, O., Lefeldt, M., Flueh, E., Solarino S., Eva, E., Eva, C., Pavan, M., Zunino, E., Scafidi, D., Spallarossa, D., Ferretti, G. , 2008. Verso una migliore conoscenza delle strutture del Mar Ligure: il progetto GROSMARIN. Rendiconti online della Società Geologica Italiana, 3: 359-360.
Dessa, J.X., Simon, S., Lelièvre, M.., Beslier, M.O., Deschamps, A., Béthoux, N., Solarino, S., Sage, F., Eva, E., Ferretti, G., Bellier, O., Eva, C., 2010. The GROSMarin Experiment: Three Dimensional Crustal Structure of the North Ligurian Margin From Refraction Tomography and Preliminary Analysis of Microseismic Measurements. Bulletin de la Societe Geologique de France, submitted.

Task D: Tsunamis

Task information

Task D Tsunamis
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Progress of the task: general

As for the "**Historical seismology and macroseismicity, included tsunamis**" available records from historical catalogues and new contemporary sources have been collected on the 1832, 1836, 1905 and 1907 Calabria tsunamis (Figure 27). Information available on the 1169, 1693, 1783 and 1908 events have been also upgraded. All the historical data have been stored in the tsunami georeferenced database. A GIS database was set up and the reconstructed data on earthquake-tsunami delay time, first tsunami arrival polarity, run-up height and inundation depth have been overlaid on geo-referenced maps. The major benefit is the possibility to combine a general view of the tsunami effects at a regional scale with the inspection of the variability of the effects themselves at very local level. The database is being integrated in the GIS database of the European Project called TRANSFER (Tsunami Risk And Strategies For the European Region), coordinated by the Department of Physics of the University of Bologna. Cooperation between RUs 6.01-6.02-6.03 and 6.05 is at a good level.

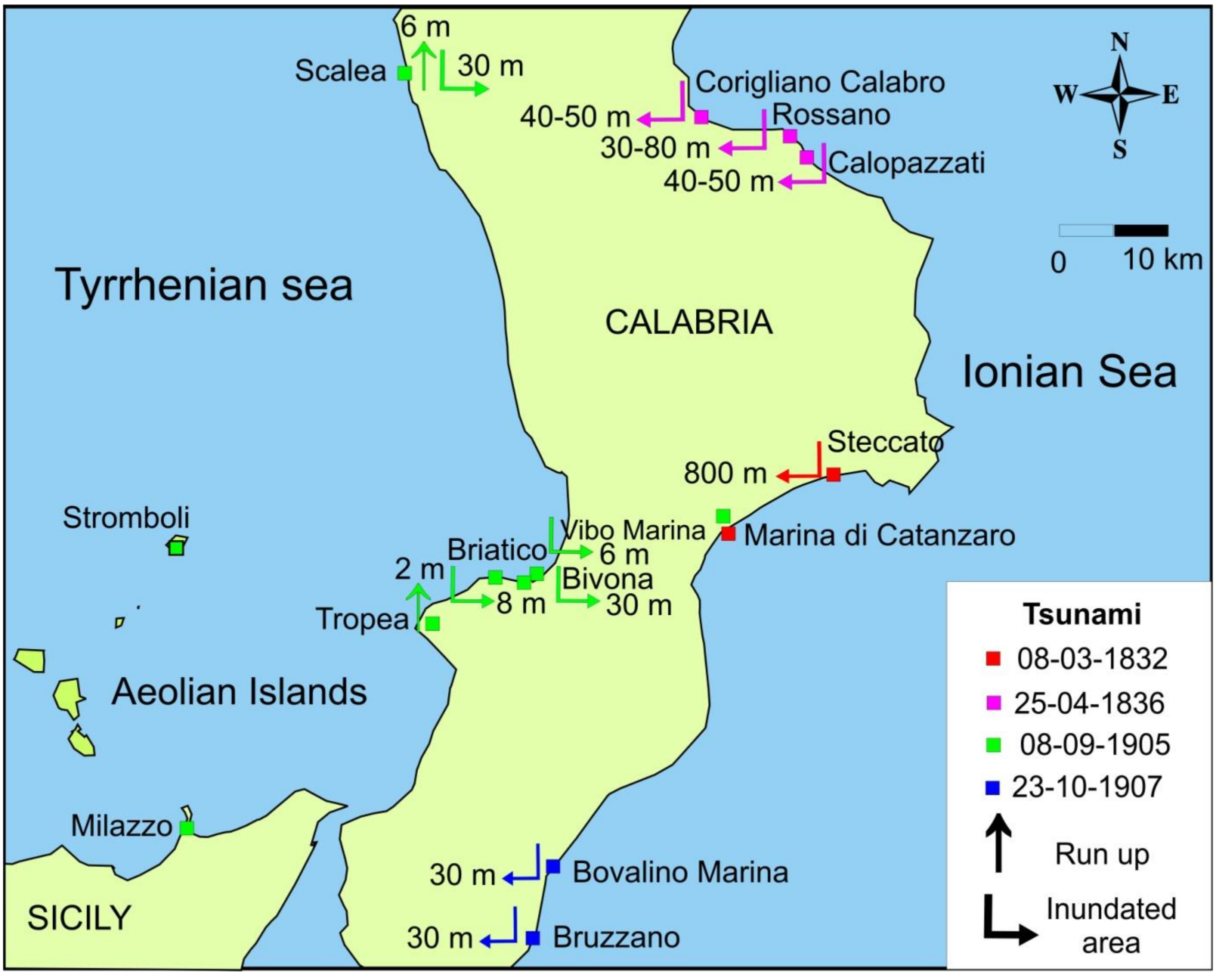

Figure 27: Locations affected by the minor Calabria tsunamis of 19th and 20th century (after RU 6.01 Barbano report).

As for the "**Tsunami deposits study**" along the coast of eastern Sicily (Figure 28), Task D researchers found evidence for the well-known 1908 tsunami probably only at Anguillara and Porto Palo sites (Barbano et al., 2009) and possibly at Morghella site too. The tsunami deposit associated with the 1783 event was identified only at the Capo Peloro site, confirming historical information that confines the effects of this tsunami to the northern part of the Messina Strait. Moreover, in this site, an anomalous layer left by a tsunami inundation that occurred in the first century A.D. was recognized (Pantosti et al., 2008). RU researchers found the deposit of the 1693 tsunami at Priolo site (De Martini et al., 2010) and probably also in Pantano Morghella, Gurna and Anguillara sites (Barbano et al., 2009), where also an anomalous layer probably associated with the 1542 tsunami was identified. At Gurna, a tsunami deposit most likely related to the 1169 inundation was also found. Moreover, at Gurna, Priolo and Morghella sites records of inundation occurred in the time interval 100–600 A.D. and 220–600 A.D. could be related to the 365 A.D. tsunami. We collected interesting evidence of paleoinundations dated about 600–400 B.C. and 975–800 B.C. at Augusta, 800–600 B.C. at Priolo (De Martini et al., 2010). Finally, evidence for a tsunami inundation occurred between 2300 and 1635 B.C. at Gurna and Priolo sites may be linked to the famous about 3600 BP Santorini event. The number of paleoevents found by this study confirms that tsunami recurrence time in eastern Sicily is about 300–400 years.

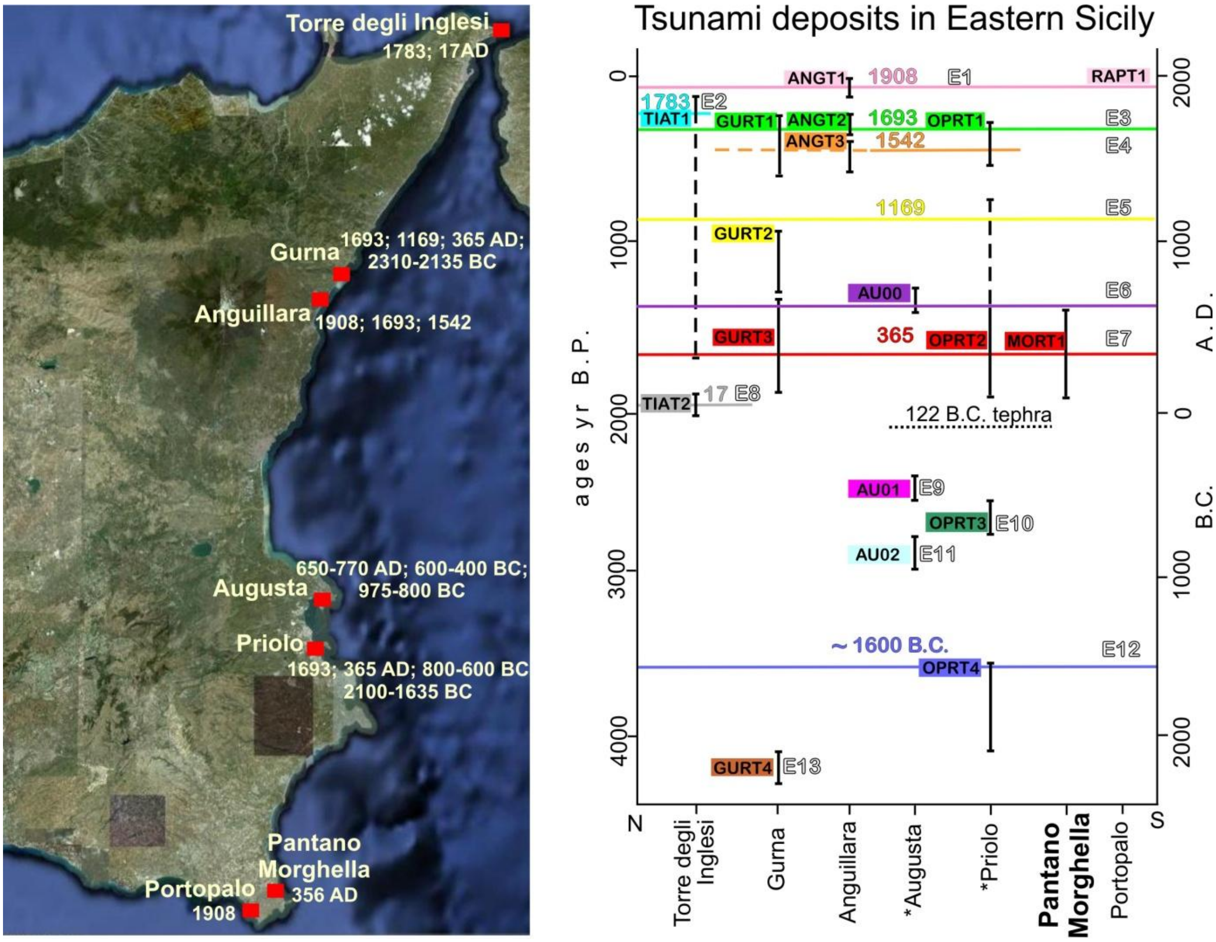

Figure 28: Space-temporal distribution of tsunami deposits identified in different sites along eastern Sicily coast to be compared with historical tsunamis. The tsunami deposits are marked with a box and the core label: black boxes = high level of confidence (the layer has the most of the identification characters of tsunami deposit); medium grey boxes = medium level of confidence (the layer has many of the identification characters of the tsunami deposit); light grey boxes = low level of confidence (the layer has some of the identification characters of the tsunami deposit). E1, E2, … E11 are the inundation events for which the relative deposits were found in eastern Sicily, marked with horizontal lines, whose length indicates extension of inundated coastline: black lines = historical tsunamis identified with their dates; grey lines = paleotsunami events. Dotted horizontal line marks the 122 B.C. tephra found in the Priolo site. Vertical lines indicate the chronological constraints for the events (modified from Barbano et al., 2009).

As for the Apulia region, north of Polignano, near the San Vito Abbay (XI-XV century), Task D researchers studied a sequence of marine sediment mixed with soil deposit directly covering the local basement, interpreted as a deposit due to the impact of a single catastrophic wave. Radiocarbon age determinations suggest the occurrence of a strong marine event in the late roman age (AD 480-850). Moreover, geomorphological evidences represented by boulders ridges/fields and sandy berms have been recognised in Torre Castiglione (Lecce) and Punta Saguerra (Taranto) sites. AMS results suggest the occurrence of two distinct tsunami events related to the 1456 earthquake and to the 1832 or 1836 Rossano earthquake (Ionian Sea coast of Calabria). In the Punta Saguerra site, the deposition of a berm of mega-boulder up to 35 ton could be related to the tsunami generated by the earthquakes occurred in 1832 or in 1836 near Rossano.

Cooperation between RUs 6.01, 6.02, 6.03 is at an excellent level.

A new geological/geophysical cruise has been organized and carried out in March-April 2008 with R/V CNR-Urania also in the frame of the "**Off-shore research of Tsunami signatures**" subject. Geophysical data have been acquired and well-targeted sediment samples have been collected in the bay of Augusta and offshore Capo Rizzuto. The results of the stratigraphic analysis of a 7.5 m piston core already collected in the bay of Augusta appear particularly promising for studying the

effect of high-energy events at a millennial scale. In fact, the multidisciplinary study of core MS-06 highlighted the occurrence, during the past 4500 yr, of at least 11 (possibly 12) anomalous events characterized by the presence of displaced epiphytic benthic foraminifera and a relative increase of grain size in the sediments. These anomalous layers could have been caused by high-energy events, with tsunamis as best candidates. This hypothesis is also supported by observation that the ages of four (possibly 5) of these high-energy events coincide with that of historical tsunamis (1908, 1693, 1169, BP 3600 Santorini and possibly AD 365 Crete). Considering the whole set of events occurred during the past 3700 yr, a rough average recurrence-time of 330-370 yr for tsunami inundations in the Augusta bay can be estimated. Cooperation between RUs 6.02 and 3.08 is at adequate level.
As for the "**Source mechanism of Calabria 1905 and Messina 1908 tsunamigenic earthquakes**" all the available tide gouge records have been digitized as well as all the available bathymetric charts needed for the modeling. Run-up heights along the coast of Sicily and Calabria for the 1908 event were collected as well as all the geodetic leveling data of the routes of Southern Calabria and Eastern Sicily. The seismic sources are not able to explain the 1908 tsunami, both in the near and in the far field. An additional source, probably a submarine landslide, is needed. The joint inversion shows that the source zone of the tsunami should be located at about 38°N, 15.5°E. Taking into account the morphological constraints, the environmental effects, the new epicentral localization and the tsunami data, the fault responsible for the 1905 Calabria earthquake is likely an offshore fault with a predominant normal mechanism.

Progress of the task by RUs

1.1.10 RU 6.01 Barbano

Historical seismology and macroseismicity, included tsunamis
The RU researchers analyzed the available records from historical catalogues and searched new contemporary sources to collect detailed data on the 1832, 1836, 1905 and 1907 Calabria tsunamis. Information available on the 1169, 1693, 1783 and 1908 events have been also upgraded including wave first motion, delay time and wave period. All the historical data have been stored in the tsunami georeferenced database.
Tsunami deposits study in eastern Sicily
In order to identify sandy tsunami deposits possibly due to tsunami waves field surveys have been carried out in the Pantano Morghella and Fiumefreddo sites (in collaboration with RU 6.02 De Martini) where researchers performed core campaigns to reconstruct the characteristic stratigraphic sequence of the site and to identify anomalous sandy sheets. At Fiumefreddo site, stratigraphical and paleontological analyses performed on a sandy layer was found at about 1.2-1.3 m depth did not furnished enough elements to interpret it as tsunami deposit (all the samples are barren). At Pantano Morghella site, sedimentologic/stratigraphic and macro-micropaleontologic analyses together with the observation of a sharp basal contact of a peculiar sandy layer (up to 8-10 cm thick at about one meter depth), its thickness decreasing with distance from the sea and its extension inland for about 1200 meters indicate that the deposit was likely deposited by a tsunami inundation.
Three radiocarbon datings constrain this sandy layer age in the interval 235-685 AD suggesting that it could represent the geological record of the 365 AD Crete tsunami. Another sandy layer found at about 30 cm depth is more recent than the AD 1685-1955 suggesting that it can represent the deposit of the 1693 or 1908 tsunami.
Moreover, the Ionian coast of south-eastern Sicily (Italy), between Brucoli and Capo Passero, is characterized by the occurrence of anomalous deposits of boulders.
The RU researchers analyzed boulders in three areas (Capo Campolato, Vendicari and San Lorenzo) in order to distinguish if they were deposited by storm or tsunami waves. The size, shape, position, pre-transport setting and long-axis orientation of about 330 boulders were investigated. Hydrodynamic transport equations were used jointly with statistical analysis of sea storms in order to determine the extreme events - geological or meteorological – responsible for these singular

accumulations. Results show that the largest storm waves were probably responsible for the current distribution of most boulders, whereas the biggest boulders at distance > 40 m are likely deposited by tsunamis.

1.1.11 RU 6.02 De Martini

Tsunami deposits study in Calabria

In order to identify sandy tsunami deposits possibly due to tsunami waves, field surveys have been carried out in the Sibari and S. Eufemia plains (in collaboration with RU 6.01 Barbano) where researchers performed core campaigns to reconstruct the characteristic stratigraphic sequence of the site and to identify anomalous sandy sheets. As for the S. Eufemia plain, it presents important human modification of the coastal areas and several sites that appeared to have a significant potential in the aerial-photographs, dated back to the 1950, at present are substantially modified. Nevertheless, the group worked in two areas: the Coastal Lakes and Maida areas. A total of 9 cores, both with hand and engine coring device, down to a maximum depth of 4.60 m, as far as 0.6 km from the present coastline were carried out. Stratigraphic and micropaleontological analyses suggest that almost all the sites investigated (Attila site being the only one exception) experienced high-energy depositional events most probably related to a fluvial environment. At the moment, we do not have any evidence for tsunami deposits in the cores, nevertheless the Attila site appears to be the only potential trap for marine inundations occurred in the Holocene along the whole S. Eufemia coastal plain. The Sibari plain presents a good potential for paleotsunami deposits recognition and the researchers concentrated on three sites that may contain the needed potential for our research: the Villapiana, Ogliastrello and Punta Alice areas where this RU worked in collaboration with RU 6.03 Mastronuzzi. We dug a total of 22 cores, to a maximum depth of 4 m, as far as 0.6 km from the present coastline. Unfortunately the recentmost Sibari plain sediments appear dominated by coarse-grained deposits (sand and gravel), particularly abundant from 4 to 2 m depth, and by medium-fine sediments (silt and silty clay), commonly found from 2 to 0 m depth. The results of the micropaleontological analysis showed that all the studied samples were barren or contained few reworked foraminifera, probably derived from the erosion of older (Pliocene and Pleistocene) terrains. This latter evidence together with the geomorphological setting of the whole plain (built up by the Sibari river) suggests that both the actual and the paleo-environment are dominated by fluvial process.

Off-shore research of Tsunami signatures

In parallel with in-land search for tsunami deposits in the Augusta Bay in Eastern Sicily, RU 6.02 research extended offshore (in collaboration with RU_3.08_Polonia) with the aim of highlighting any subtle anomaly in the sediments, fauna assemblages, physical properties, etc. that could represent a proxy for tsunami occurrence. Two cores were sampled in the Augusta bay (110 cm at 70 m water depth) and offshore Crotone (150 cm at 50 m water depth). The two cores are now stored in the CNR-ISMAR-Bologna laboratory and some analyses are in progress. Our idea is to replay the experience done with the core MS-06 sampled in the Augusta off-shore during the previous INGV-DPC agreement, in order to verify if the findings done (Smedile et al., 2010, submitted) will be confirmed for the Augusta Bay area and to test this approach in the Crotone off-shore. Our approach involved the study of geophysical data (morphobathymetry, seismic reflection, seafloor reflectivity) and sediment samples, including X-ray imaging, physical properties, isotopic dating, tephrochronology, grain-size and micropaleontology. As for the Augusta Bay off-shore area (Eastern Sicily), eleven anomalous layers marked by high concentration of displaced epiphytic foraminifera and subtle grain size changes were found in a 6.7 m long, fine sediment core (MS-06), sampled 2 km offshore the Augusta harbor at 72 m depth and recording the past 4500 yr of deposition. Because concentrations of epiphytic foraminifera are quite common in infralittoral zones, but not expected at -70 m, we advanced the hypothesis that these anomalous layers might be related to the occurrence of tsunamis causing substantial uprooting and seaward displacement of

Poseidonia oceanica blades with their benthic biota. Correlations between anomalous layers and tsunamis events have been supported by a multivariate analysis on benthic foraminifera assemblage and ages of historical tsunamis record. We found that four out of the eleven layers were embedded in age intervals encompassing the date of major tsunamis that hit eastern Sicily (1908, 1693, 1169) and the broader Eastern Mediterranean (Santorini at about BP 3600). One more layer, even if less distinct than the others, was also defined and may be the evidence for the AD 365 Crete tsunami. Moreover, a high-resolution paleomagnetic and rock magnetic study of the two cores, MS06 and MS06-SW (6.7 and 1.1 m long, respectively) collected in the Augusta Bay shelf was done. Paleomagnetic data allowed the identification of a well-defined characteristic remanent magnetization, which provides a high-resolution record of paleosecular variation (PSV) at the sampling site. The reconstructed PSV curve is in good agreement with the available reference PSV curves for the Mediterranean region and with the prediction from recent PSV modelling for Europe.

1.1.12 RU 6.03 Mastronuzzi

Historical seismology and macroseismicity, included tsunamis

The UR researchers analyzed the available records from historical catalogues and searched new contemporary sources to collect detailed data on the 1832, 1836 tsunamis along the Calabria coast.

Tsunami deposits study

The group performed geomorphologic study of the following areas:

Apulia region – the coastal areas of Polignano (Bari), Torre Castiglione (Lecce) and Punta Saguerra (Taranto); *Calabria region* – the coastal areas of Rossano Calabro (Cosenza), Punta Alice - Cirò (Crotone) and Le Castella (Crotone); *Sicily region* – the coastal area from Capo Passero to Augusta (Siracusa).

The field surveys performed in the second and in the third areas were organised in coordination with the RU 6.01 managed by Prof.ssa S. Barbano (University of Catania) and RU 6.02 managed by Dr. Paolo Marco De Martini (INGV – Roma).

As for the sites located in *Apulia*:

north of Polignano, near the San Vito Abbay (XI-XV century), the coast is marked by the presence of a low cliff , no more than 1 m high, shaped in a sequence of marine sediment mixed with soil deposit directly covering the local basement. The sequence has been interpreted as a deposit due to the impact of a single catastrophic wave. 14C age determinations were performed on two marine gastropod samples. The obtained ages indicate the impact of a strong marine event in the late roman age (AD 480-850). Moreover, geomorphological evidences represented by boulders ridges/fields and sandy berms have been recognised in Torre Castiglione (Lecce) and Punta Saguerra (Taranto) sites. In the Torre Castiglione site, three AMS 14C age determinations have been performed on marine gastropod samples coming from the sandy berm and on vermetids shells that encrustate the boulders surfaces, the results suggest the occurrence of two distinct tsunami events related to the 1456 earthquake and to the Rossano earthquakes. Unluckily the reliability of the 14C age determinations did not permit to discriminate between the 1832 and the 1836 event. In the Punta Saguerra site, a berm of mega-boulder up to 35 ton heavy is elongated about parallel to the coastline; the geochronological data yielded by AMS analyses performed on bio-concretions collected on the biggest boulder surfaces, permit to correlate the deposition of this landform to the impact of the tsunami generated by the earthquakes occurred in 1832 or in 1836 near Rossano along the Ionian coast of Calabria.

As for the sites located in *Calabria*:

the coastal area elongated on the Ionian side of the Calabria from Rossano to Punta Alice is formed by the coalescence of fluvial deltas, filled swampy basins and dunes in part destroyed by human activity. In general, the coastline is affected by a retreating trend, likely caused by reduced debris supply by the rivers. In these localities, some exploratory cores have been performed in collaboration with the RU 6.02 managed by Dr. P.M. De Martini. Moreover, morphological surveys have been performed directly on the field and by means of remote sensing in order to individuate possible over

sized landforms which origin could be put in relation to extreme waves impact. Despite the fact that the historical chronicle of the April 28, 1836 earthquake indicates that in these localities the tsunami penetrate about 40 m inland, the obtained sedimentological and morphological results didn't show any evidence. At Le Castella site, the deposits are made by sands and calcarenites, locally well cemented; the wave cut platforms guest few boulders scraped from the underwater cliff or collapsed from the emerged part of it, some have been scattered inland from the inertidal/sublitoral areas; unluckily the absence of biogenic encrustations did not permit to evaluate the distance and the depth of provenience, neither to perform on them AMS 14C age determinations to know the age of their scatters. The presence of these few boulders and their morphological and statistical analysis seem to indicate that they have been distribute in place by extreme waves.
As for the sites located in *Sicily*:
the coastal area stretching from Augusta to Capo Passero is marked by gently slope rocky coasts and cliff no more than 10 m high. In several sites, large boulders scraped from the sea bottom or from the top of the cliff and scattered inland, forms extent boulder fields, boulder berms or were deposited isolated. Their deposition was attributed at least to three different tsunamis that hit the eastern coast of Sicily on February 4, 1169, on January 11, 1693 and on December 28, 1908 (Scicchitano et al., 2007). Recent surveys, using classical topographic method to try to discriminate between tsunami and exceptional storm accumulation (Barbano et al., 2010), evidenced that exceptional storms occurred on November 2008 and on February 2009 have been able to detach and scatter inland boulders. Nevertheless, detailed topographic and geomorphological surveys have been performed by means of DGPS and LASER SCANNER techniques in order to improve and validate the hydrodynamic and morphodynamic model elaborated by Pignatelli et al. (2009). Underwater morphological surveys have been performed up to the bathymetry 20 m to evaluate the energetic wave behaviour during the approaching to the coastline. The post processing of the enormous quantity of data surveyed is still in progress.

1.1.13 RU 6.04 Piatanesi

Source mechanism of Calabria 1905 and Messina 1908 tsunamigenic earthquakes
As for the 1908 Messina event, the RU researchers have manually digitized all available tsunami waveforms and in particular the tide-gage records. Later these data have been post-processed to extract the tsunami signal. The RU completed the collection of the nautical charts to built-up a detailed bathymetric model of the harbors where mareographs are placed. From the available literature and by directly contacting the authors, the RU researchers collected the run-up data along the coast of Sicily and Calabria as well as the geodetic data of the leveling routes in Calabria and Sicily. Several scenarios, by means of forward and inverse modelling were tested. RU researchers performed a joint inversion using tide-gauges, run-up, and leveling data to infer the initial displacement of the 1908 Messina tsunami causative source. The conclusions are as follows: a) the seismic sources are not able to explain the 1908 tsunami, both in the near (run-up data) and in the far (marigrams) field. An additional source, probably a submarine landslide, is needed; b) the joint inversion shows that the source zone of the tsunami should be located at about 38°N, 15.5°E; c) a reasonable time shift (2-3 minutes) between the earthquake and the slide initiation should be allowed: this will produce a better fit at Malta tide-gauge. As for the 1905 Calabria event, RU researchers took into account 7 seismic sources recently proposed by Tertulliani and Cucci (2009) as potential candidates for the 1905 earthquake. The tsunami generated by these sources were modelled and compared to the synthetic and recorded marigrams at Napoli, Ischia and Civitavecchia. Taking into account the morphological constraints, the environmental effects (Tertulliani and Cucci, 2009), the new epicentral localization (Michelini et al., 2006) and the tsunami data, the fault responsible for the 1905 Calabria earthquake is likely an offshore fault, with a normal mechanism and small right-lateral component, striking about 100° and dipping 60°-80°.

1.1.14 RU 6.05 Tinti

Historical seismology and macroseismicity, included tsunamis

RU researchers undertook a systematic revision of the Italian Tsunami Catalogue (ITC, see Tinti et al., 2004; most recent official version (2007) downloadable at http://portale.ingv.it/servizi-e-risorse/BD/catalogo-tsunami/catalogo-degli-tsunami-italiani). In the present structure of ITC the Italian area is divided in a number of sub-regions, characterized by different rates of tsunami activity. The regions presenting the highest rates are found in southern Italy and are Tyrrhenian and Ionian Calabria, the Aeolian Islands, the Messina Straits and eastern Sicily. With the exception of the Aeolian archipelago, where tsunami occurrences are mainly related to the volcanic activity of the islands, in all the other aforementioned sub-regions tsunamis are typically generated by earthquakes or by landslides set in motion by the earthquakes. The revision focuses on tsunamis occurred in the area including Calabria and Sicily. Although no new events were found, the revision allowed re-assessing some important parameters of tsunamis, like e.g. intensity. Moreover, for the events occurred on 11 January 1693 and 28 December 1908, the updated catalogue highlights the possibility that a significant role in the tsunami generation was played by a submarine landslide set in motion by the parent earthquakes. The updated catalogue has been implemented into a digital database in ArcGIS 9.2. For each event, it is possible to query the database to obtain the main parameters of the selected event through the "Identify" tool and to retrieve a text file containing the full description of the event itself by means of the "Hyperlink" tool. Special attention has been devoted to the re-analysis of the Messina Straits tsunami occurred on 28 December 1908. This event is particularly suitable for a deep scientific revision and for the implementation into a GIS environment due to the very large amount of historical sources and past and recent studies available. We focused on three main aspects of the tsunami impact in different localities in Sicily and Calabria: 1) the time delay between the earthquake occurrence and the arrival of the first significant tsunami signal (together with its polarity), 2) the maximum run-up, 3) the maximum inundation length.

1.1.15 RU 3.08 Polonia

Off-shore research of Tsunami signatures

A new geological/geophysical cruise has been organized and carried out in March-April 2008 with R/V CNR-Urania in the frame of CNR and MIUR related projects. Geophysical data (MCS and CHIRP profiles) have been acquired and well-targeted sediment samples have been collected in tectonically controlled sedimentary basins and across active faults.
The ISMAR-Bo "Tsunami" operating unit in cooperation with RU 6.02 De Martini carried out several activities that could be synthetically listed as follows: a) stratigraphic analysis of a 7.5 m piston core collected in the bay of Augusta that appears particularly promising for studying the effect of high-energy events at a millennial scale (Smedile et al., 2010); b) seismostratigraphic analysis of chirp-sonar profiles in the bay of Augusta; c) collection of a 1.2 m long sediment-water core, to calibrate stratigraphy of the uppermost sedimentary sequence, not reliable in piston or gravity cores, d) collection of a 1.55 m long gravity core offshore Capo Rizzuto. Results obtained are presented in the RU 6.02 De Martini section.

Deliverables

Deliverable n.	Progress %	Deliverable name
D6.01.1	100	Upgrading the Catalogo degli Tsunami Italiani (Tinti et al., 2007)
D6.01.2	100	Tables: maximum run-up, maximum inundation distance, tsunami recurrence (Sicily-Calabria).
D6.01.3	100	Studied historical tsunami table (Sicily-Calabria).
D6.01.4	100	Paleo-tsunamis (Sicily-Calabria) table

D6.01.5	100	Core and trench logs (Sicily-Calabria)
D6.02.1	100	Upgrading the Catalogo degli Tsunami Italiani (Tinti et al., 2007)
D6.02.2	100	Tables: maximum run-up, maximum inundation distance, tsunami recurrence (Sicily-Calabria).
D6.02.3	100	Studied historical tsunami table (Sicily-Calabria).
D6.02.4	100	Paleo-tsunamis (Sicily-Calabria) table
D6.02.5	100	Core and trench logs (Sicily-Calabria)
D6.03.1	100	Upgrading the Catalogo degli Tsunami Italiani (Tinti et al., 2007)
D6.03.2	100	Tables: maximum run-up, maximum inundation distance, tsunami recurrence (Calabria).
D6.03.3	100	Studied historical tsunami table (Calabria).
D6.03.4	100	Paleo-tsunamis (Calabria) table
D6.03.5	100	Core and trench logs (Calabria)
D6.04.1	100	Source mechanism of the 1908 Messina and 1905 Calabria earthquakes
D6.05.1	100	Upgrading the Catalogo degli Tsunami Italiani (Tinti et al., 2007)
D6.05.3	100	Studied historical tsunami table (Sicily-Calabria).

Management

We organized two meetings at the end of the first semester and of the first year of activity. The cooperation and interaction between different RUs have been strongly encouraged and the scientific exchanges reached a good level.

The groups (RU 6.01-6.02-6.03) cooperated in the field both for the sites selection and to perform exploratory cores in Eastern Sicily and Calabria. RU 6.01 and 6.02 collaborated for the stratigraphic, sedimentologic and dating analyses of the cored deposits.

RU 6.01 and 6.05 were in contact to select the new historical accounts that will upgrade the Catalogo degli Tsunami Italiani (Tinti et al., 2007).

RU 6.04 was in contact with RU 6.01 and 6.02 to obtain the more complete dataset of run-up data for the 1908 Messina Straits earthquake.

RU 6.02 and RU 3.08 cooperated for the sites selection where to perform geophysical investigation and coring in Eastern Sicily and Southern Calabria as well as for the stratigraphic and seismostratigraphic analyses of the data already collected.

Problems and difficulties

Most of the selected sites are flooded in autumn and wintertime; so exploratory cores to detect tsunami deposits and their geometry were performed only in late summer when the sites are wet. The few available radiocarbon datings did not allow to better constrain the age of some inundation events. The investigations in the Calabria area did not succeeded in terms of tsunami deposits detection. For most of the sites we were not able to estimate the maximum run-up, lacking time to perform detailed targeted topographic surveys.

Main key publications

Antonioli F., Ferranti L., Fontana A., Amorosi A., Bondesan A., Braitenberg C., Dutton A., Fontolan G., Furlani S., Lambeck K., Mastronuzzi G., Monaco C., Spada G., Stocchi P. (2009). *Holocene relative sea-level changes and tectonic movements along the Italian coastline*. Quaternary International, 206, 102-133.

Argnani, A., Chiocci, F.L., Tinti, S., Bosman, A., Lodi, M.V., Pagnoni, G., Zaniboni F., 2009. Comment on “On the cause of the 1908 Messina tsunami, southern Italy” by Andrea Billi et al. Geophys. Res. Lett. 36, 13, doi:10.1029/2009GL037332.

Barbano, M.S., De Martini, P.M., Pantosti, D., Smedile, A., Del Carlo, P., Gerardi, F., Guarnieri, P., Pirrotta, C., 2009. In search of tsunami deposits along the eastern coast of Sicily (Italy): state of the art. In: “Recent Progress on Earthquake Geology” (edited by P.P. Guarnieri), Novascience Publishers: 109-146.

Barbano, M.S., Pirrotta, C., Gerardi, F., 2010. Large boulders along the south-eastern Ionian coast of Sicily: storm or tsunami deposits? Marine Geology, in press. DOI: 10.1016/j.margeo.2010.05.005.
Gerardi, F., Barbano, M.S., De Martini P.M., Pantosti D., 2008. Discrimination of the nature of tsunami sources (earthquake vs. landslide) on the basis of historical data in eastern Sicily and southern Calabria. Bull. Seism. Soc. Am., 98 (6): 2795–2805.
Guarnieri, P., Pirrotta, C., Barbano, M.S., De Martini, P. M., Pantosti, D., Gerardi, F., Smedile, A., 2009. Paleoseismic investigation of historical liquefaction along the Ionian coasts of Sicily. Journal of Earthquake Engineering, 13, 68–79, DOI: 10.1080/13632460802212030.
Marsico A., Pignatelli C., Piscitelli A., Mastronuzzi G., Pennetta L. (2009). *Ricostruzione digitale di blocchi accumulati da eventi estremi in Italia meridionale.* Atti 13[a] Conferenza Nazionale ASITA, 1 – 4 dicembre 2009, 1377-1385.
Mastronuzzi G., Brückner H., Sansò P., Vött A. (2010). *An introduction to palaeo-tsunami research.* Zeitschrift für Geomorphologie, 54, 3, V-XIII.
Pantosti, D., Barbano, M.S., Smedile, A., De Martini, P.M., Tigano, G., 2008. Geological Evidence of Paleotsunamis at Torre degli Inglesi (northeast Sicily). Geophys. Res. Lett., 35: L05311.
Piatanesi, A., S. Lorito e F. Romano (2008): Il grande maremoto del 1908: analisi e modellazione, pp. 183-196, in "*Il terremoto e il maremoto del 28 dicembre 1908: analisi sismologica, impatto e prospettive"* a cura di G. Bertolaso, E. Boschi, E. Guidoboni e G. Valensise, DPC-INGV, Roma-Bologna, 2008, 813 pp
Pignatelli C., De Leonardis M., Mastronuzzi G., Sansò P. (2008). *Valutazione di impatto di onde estreme lungo la costa fra Capo San Vito e Polignano (Puglia, Italia) mediante tecniche GIS.* Mem. Descr. Carta Geol. D'It., LXXVIII, 207-222.
Pignatelli C., Piscitelli A., Damato B., Mastronuzzi G. (2010). *Estimation of the value of Manning's coefficient using Terrestrial Laser Scanner techniques*. Zeitschrift für Geomorphologie, 54, 3, 317-336.
Pignatelli C., Sansò P., Mastronuzzi G. (2009). *Evaluation of tsunami flooding using geomorphologic evidence.* Marine Geology, 260, 6-18.
Pino, N.A., A. Piatanesi, G. Valensise and E. Boschi (2009): The 28 December 1908 Messina Straits earthquake (Mw 7.1): a great earthquake throughout a century of seismology, *Seismol. Res. Lett.*, 80(2), 243-259, doi: 10.1785/gssrl.80.2.243.
Piscitelli A., Pignatelli C., Mastronuzzi G. (2009). *Hydrodynamic equations to evaluate the impact of extreme storms on the Adriatic coast of Apulia (Southern Italy).* In: Damiani L., Mossa M. (eds) Coastlab 08 - Bari, Application of Physical Modelling to Port and Coastal Protection, 351-358, ISBN 978-90-78046-07-3.

Volumes

Mastronuzzi, G., Milella, M., Pignatelli, C., Sansò, P., Selleri, G., 2008. 2nd International Tsunami Field Symposium. Ostuni (Puglia, Italy) – Lefkas (Ionian Islands, Greece), 21-27 September 2003, GI^{2}S Coast Coast – Gruppo Informale di Studi Costieri, Research Publication, 6, 202 pp, Digilabs s.r.l., Bari.
Mastronuzzi, G., Sansò, P., Bruckner, H., Pignatelli, C., Vott, A., Caputo, R., Coppola, D., Di Bucci, D., Fracassi, U., May, S.M., Milella, M., Selleri, G., 2008. Paleotsunami imprints along the coast of the central Mediterranean sea. 2nd International Tsunami Field Symposium. Ostuni (Puglia, Italy) – Lefkas (Ionian Islands, Greece), 21-27 September 2003, GI^{2}S Coast Coast – Gruppo Informale di Studi Costieri, Research Publication, 7, 198 pp, Digilabs s.r.l., Bari.
Mastronuzzi, G., Bruckner, H., Sansò, P., C., Vott, A. (Eds) (2010). Tsunami – an Tsunami - an hazard for any coast. Zeitschrift für Geomorphologie, 54, 3.

Abstracts

Barbano, M.S., De Martini, P.M., Gerardi, F., Pirrotta, C., Smedile, A., Pinzi., S., 2009. Identification of tsunami deposits in south-eastern Sicily: evidence of the 365 A.D. Crete earthquake? Convegno del Gruppo Nazionale di Geofisica della Terra Solida, Trieste, 16-19 Novembre: 83-86. ISBN 88-902101-4-1

Barbano, M.S., Pirrotta, C., Gerardi, F., 2009. Large boulders along the coast of the Vendicari Reserve (south-eastern Sicily): an approach to discriminate between storm and tsunami deposits. XXVIII convegno del Gruppo Nazionale di Geofisica della Terra Solida, Trieste, 16-19 Novembre. 80-83. ISBN 88-902101-4-1

De Martini, P.M, Barbano, M.S, Smedile, A., Gerardi, F, Pantosti, D,, Del Carlo, P., Pirrotta, C., 2009. Late Holocene record of tsunamis in the Augusta Bay area (eastern Sicily, Italy): historical vs geological data. AGU Fall Meeting San Francisco December 14–18 2009, Eos Trans. AGU, 90 (52), Fall Meet. Suppl., Abstract NH31B-1121.

Gallais F., M.-A. Gutscher, L. Torelli, A. Polonia, D. Graindorge, 2010**.** The Calabrian subduction zone (Ionian Sea): historical seismicity and a new review of the system from multi-channel seismic data. European Geosciences Union, General Assembly 2010, Vienna, Austria.

Gerardi, F., Barbano, M.S., De Martini, P.M., Pirrotta, C., Smedile, A., Pinzi., S., Del Carlo, P., 2010. Geological record of the 365 A.D. Crete tsunami in south-eastern Sicily. Geophysical Research Abstracts. Vol. 12, EGU2010-756, EGU General Assembly Vienna 3-6 may 2010.

Gerardi, F., Marsico, A., Pignatelli, C., Pirrotta, C., Barbano, M.S., Mastronuzzi, G., 2009. Terrestrial laser scanner technique: 3D reconstruction of Vendicari and San Lorenzo boulders (southern-eastern Sicily, southern Italy). Convegno Nazionale AIGeo, Modena, 14-18 Settembre 2009.

Lorito, S., Piatanesi A., Romano, F., Vinci S. and Boschi E., 2008. The Messina Straits 1908 Tsunami: Observations and Causative Source. Eos Trans. AGU, 89(53), Fall Meet. Suppl. Abstract S41D-08.

Milella De Santis V., Pignatelli C., Cacciapaglia G., Selleri G., Fozzati L., Mastronuzzi G., Sansò P., Palmentola G. (2008). *Sensibilità della costa pugliese alle ondazioni estreme*. Convegno Nazionale "Coste: Prevenire, Programmare, Pianificare", Maratea (Pz), 15-17 Maggio 2008, Autorità Interregionale di Bacino della Basilicata, Studi e ricerche, II, 9, 477-487.

Milella M., De Santis V., Pignatelli C., Cacciapaglia G., Selleri G., Fozzati L., Mastronuzzi G., Sansò P., Palmentola G. (2008). *Sensibilita' dei siti archeologici della costa pugliese alle ondazioni estreme*. Atti AIA-Sub, Manfredonia (FG) 4-6 ottobre, accepted, in press.

Pirrotta, C., Barbano, M.S., Gerardi, F., 2010. Analysis of large boulders along the coast of south-eastern Sicily to discriminate between storm and tsunami deposits. Geophysical Research Abstracts Vol. 12, EGU2010-752, EGU General Assembly Vienna 3-6 May 2010.

Polonia A., L. Torelli, F. Riminucci, L. Gasperini, M.-A. Gutscher, P. F. Gallais, Mussoni, L.G. Bellucci, L. Capotondi, 2010. The Calabrian Arc subduction system: active faults, mud diapirism and the geological record of catastrophyc events in the subsurface. 39th CIESM Congress, Venice, 10-14 May 2010.

Polonia A., L. Torelli, F. Riminucci, P. Mussoni, D. Kläschen, M.-A- Gutscher, F. Gallais, 2010. The Calabrian Arc subduction complex in the Ionian Sea. European Geosciences Union, General Assembly 2010, Vienna, Austria.

Riminucci F., A. Polonia, L. Torelli, P. Mussoni, 2010. Seafloor morphology in the different domains of the Calabrian Arc subduction complex– Ionian Sea. European Geosciences Union, General Assembly 2010, Vienna, Austria.

Romano, F., Piatanesi A. , Lorito S., Vinci S. and Boschi E., 2009. The Messina Straits 1908 tsunami: tide-gage, run-up and the causative source. Geophysical Research Abstracts, Vol. 11, EGU2009-5180, 2009.

Sagnotti, L., Smedile, A., De Martini, P.M., Pantosti, D., Speranza, F., Winkler, A., Del Carlo, P., Bellucci, L., 2010. A continuous paleosecular variation record of the last 4 millennia from the

Augusta bay (Sicily, Italy). Abstract presented at the EGU General Assembly 2010, Wien (Austria), May 2-7 2010.
Smedile, A., De Martini, P.M., Barbano, M.S., Pantosti, D., Gerardi, F., Del Carlo, P., Bellucci, L., Gasperini, L., Sagnotti, L., Polonia, A., Pirrotta, C., 2008. Paleotsunami Evidence in the Augusta Bay (Eastern Sicily, Italy). Abstract presented at the Agu Fall Meeting, San Francisco, 15-19 December, 2008. Eos Trans. AGU, 89 (53), Fall Meet. Suppl., Abstract OS53A-1293.
Smedile, A., De Martini, P.M., Bellucci, L., Gasperini, L., Sagnotti, L., Del Carlo, P., Polonia, A., Pantosti, D., Barbano, M.S., Gerardi, F., 2008. Paleotsunami deposits in the Augusta Bay area (Eastern Sicily, Italy): preliminary results from offshore data. Rendiconti online Soc. Geol. It. , 3: 770-771.
Tinti, S., Gallazzi, S., Armigliato, A., Tonini, R., Pagnoni, G., Manucci, A., 2010. Updating of the Italian Tsunami Catalogue for southern Italy with special emphasis on the reconstruction of the 1908 Messina Straits tsunami effects. Abstract and poster presented at the EGU General Assembly 2010, Vienna (Austria), May 2-7 2010 (also in Geophysical Research Abstracts, Vol. 12, EGU2010-6680).

Submitted manuscripts

Barbano, M.S., Pirrotta, C., Gerardi, F., 2010. Differentiating between boulders deposited by tsunamis and storm waves along the south-eastern Ionian coast of Sicily (Italy). Submitted BGTA.
De Martini, P.M., Barbano, M.S., Smedile, A., Gerardi, F., Pantosti, D., Del Carlo, P., Pirrotta, C., 2010. A unique 4000 yrs long geological record of multiple tsunami inundations in the Augusta Bay (eastern Sicily, Italy). Submitted to Marine Geology.
Mastronuzzi G. (2010). *Tsunami in Mediterranean sea.* Egyptian Journal of Environmental Change, accepted
Pignatelli C., Ferilli S., Capolongo D., Marsico A., Milella M., Pennetta L., Piscitelli A., Mastronuzzi G. (2010). *Evidenze morfologiche, rilievo digitale ed applicazioni informatiche al fine della valutazione del limite di inondazione da tsunami*. Italian Journal of Remote Sensing, accepted, in press
Polonia A., Torelli L., Gasperini L., Riminucci F., Mussoni P., Gallais F., Gutscher M.-A., Artoni A., and Klaeschen D. The Calabrian Arc subduction complex in the Ionian sea: regional architecture, active deformation and seismic hazard. Submitted to Tectonics.
Smedile, A., De Martini, P.M., Pantosti, D., Bellucci, L., Del Carlo, P., Gasperini L., Pirrotta C., Polonia, A., Boschi, E., 2010. Possible tsunami signatures from an integrated study in the Augusta Bay offshore (Eastern Sicily – Italy). Submitted to Marine Geology.