*Agreement INGV-DPC 2007-2009*

# Project S5 : "High-resolution multi-disciplinary monitoring of active fault test-site areas in Italy"

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project web site: http://dpc-s5.rm.ingv.it/

## Deliverables - I phase

*May 1st, 2008 – April 30th, 2009 (delayed to May 22nd )*

Deliverable D1
Title: Standard modular automatic procedures for the management and analysis of a continuous seismic data stream an application to L'Aquila sequence

*end of phase I*

*prepared by:*
*Task 2 UR3 WP 1.1 Resp. Raffaele Di Stefano, INGV CNT*

## 1. Description of the Deliverable

We decided to apply the refined procedure to a subset of data that struck the Abruzzi region since April 6, 2009. We analysed waveforms recorded by 20 temporary seismic stations (INGV Emergency Network), installed in the epicentral area soon after the mainshock (Mw 6.3) occurrence. In order to quickly identify seismic events, we skipped the triggering steps and we selected ~1200 P-wave pickings at one station (AQU) seismic station furnished by the Earthworm acquisition system, to be used as reference triggers for the procedure. To locate events, we used a reference 1D velocity model optimized for the area (Bagh et al., 2007). Improved final locations for 1100 events with $M_L$ in the 2.0 and 4.8 range (see Figure 1a and 1b in the Supplementary Material) were obtained by using the double-difference algorithm (HypoDD; Waldhauser and Ellsworth, 2000). Vertical cross sections through the aftershocks clearly show the geometry of the fault planes activated during the sequence. These results let us foresee the potentiality of the improved procedure.

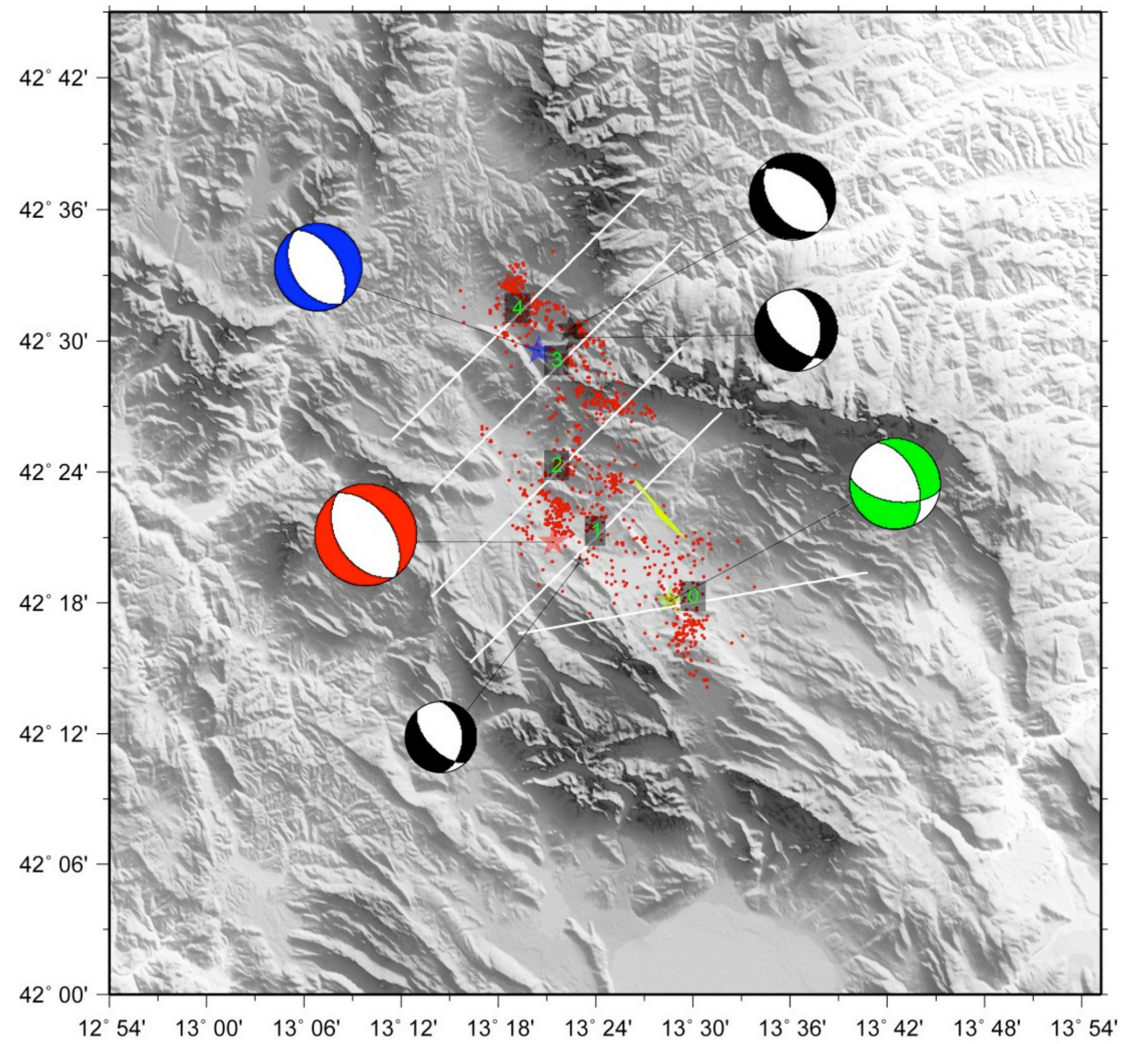


*Figure 1a– Map of the seismicity occurred in the L'Aquila area in between the 10th and the 14th of April 2009. We report also location and focal mechanism of the foreshocks and the three main events of the sequence, while at the north-eastern sector we report location and focal mechanisms of two events with ML>4 automatically detected, picked and located with the developed procedure. See text for details.*

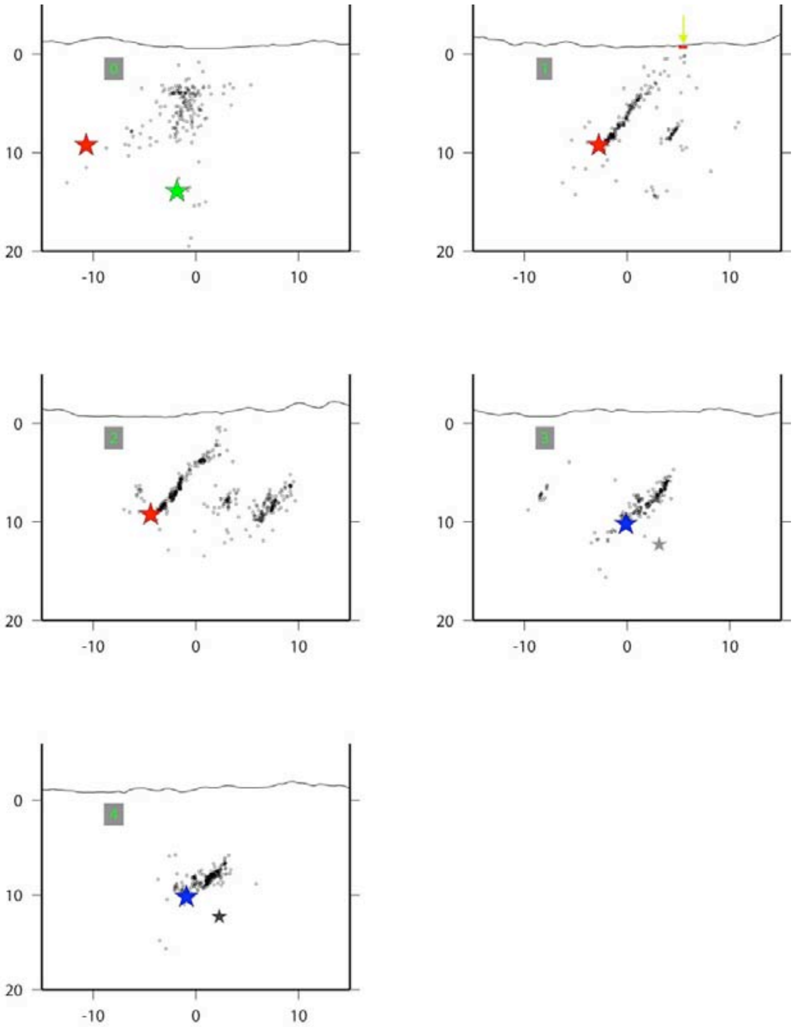


*Figure b – Vertical cross sections of the seismicity of figure 1a*

**2. Relevance for DPC and/or for the scientific community**

This deliverable produce quick and refined location of microseismicity starting from continuous recordings at seismic stations

**3. Changes with respect to the original plans and reasons for it**

The deliverable is declared for the end of the project but we considered interesting to show her the application on L'Aquila seismic sequence.

**4. References**

Aldersons, F., 2004. Toward a three-dimensional crustal structure of the Dead Sea region from local earthquake tomography, PhD Thesis, Tel Aviv University.

Bagh S., L. Chiaraluce, P. De Gori, M. Moretti, A. Govoni, C. Chiarabba, P. Di Bartolomeo c, M. Romanelli. Background seismicity in the Central Apennines of Italy: The Abruzzo region case study. Tectonophysics 444 (2007) 80–92

Di Stefano, R., Aldersons, F., Kissling E., Baccheschi P., Chiarabba C., Giardini D., 2006. Automatic seismic phase picking and consistent observation error assessment; application to the italian seismicity. Geophys. J. Int, 165-1, 121-134.

Lahr, J.C., 1989. HYPOELLIPSE/version 2.00: a computer program for determining local earthquakes hypocentral parameters, magnitude and first motion pattern. U.S. Geol. Surv Open-File Rep., vol. 89-116, p. 92.
Montalbetti, J. F., and E. R. Kanasewich (1970), Enhancement of teleseismic body phases with a polarization filter, Geophys. J. Int., 21, 119–129, doi:10.1111/j.1365-246X.1970.tb01771.x.
Valoroso L., L. Improta, L. Chiaraluce, R. Di Stefano, L. Ferranti, A. Govoni and C. Chiarabba, 2009. Active faults and induced seismicity in the Val d'Agri area (Southern Apennines, Italy). Geoph. Journal Intern. doi:10.1111/j.1365-246X.2009.04166.x.
Waldhauser, F., and W. L. Ellsworth (2000), A double-difference earthquake location algorithm: Method and application to the northern Hayward Fault, California, Bull. Seismol. Soc. Am., 90, 1353– 1368.

**5. Key publications/presentation**

*Will follow*

Deliverable D6
Title: Preliminary Balanced geological sections, derived from depth converted seismic profiles at ATF test site

*end of phase I*

*prepared by:*
*Task 2 UR3 WP 1.4 Resp.Francesco Mirabella Universita' di PG*

## 1.**Description of the Deliverable**

The main topics addressed by WP1.4 concern the coherent re-interpretation of the seismic data, calibration with boreholes and surface geology, estimation of the velocity field through the wells sonic logs for the depth conversion of the reflectors and the sequential restoration of the extensional structures. The data, after being gathered and projected/reprojected into the same geographical reference system with GIS tools, were loaded into the Move$^{TM}$ package which allows the depth conversion and sequential balancing of the geological sections to be made. The sequential restoration and balancing was addressed along two sections (L1 and L2 in figure 1 in D6 deliverable) which cross the region between the Tiber Valley and the Gubbio anticline. The interpretation of these two sections is tied to the stratigraphy of three boreholes, S.Donato1, M.Civitello1 and Perugia2.

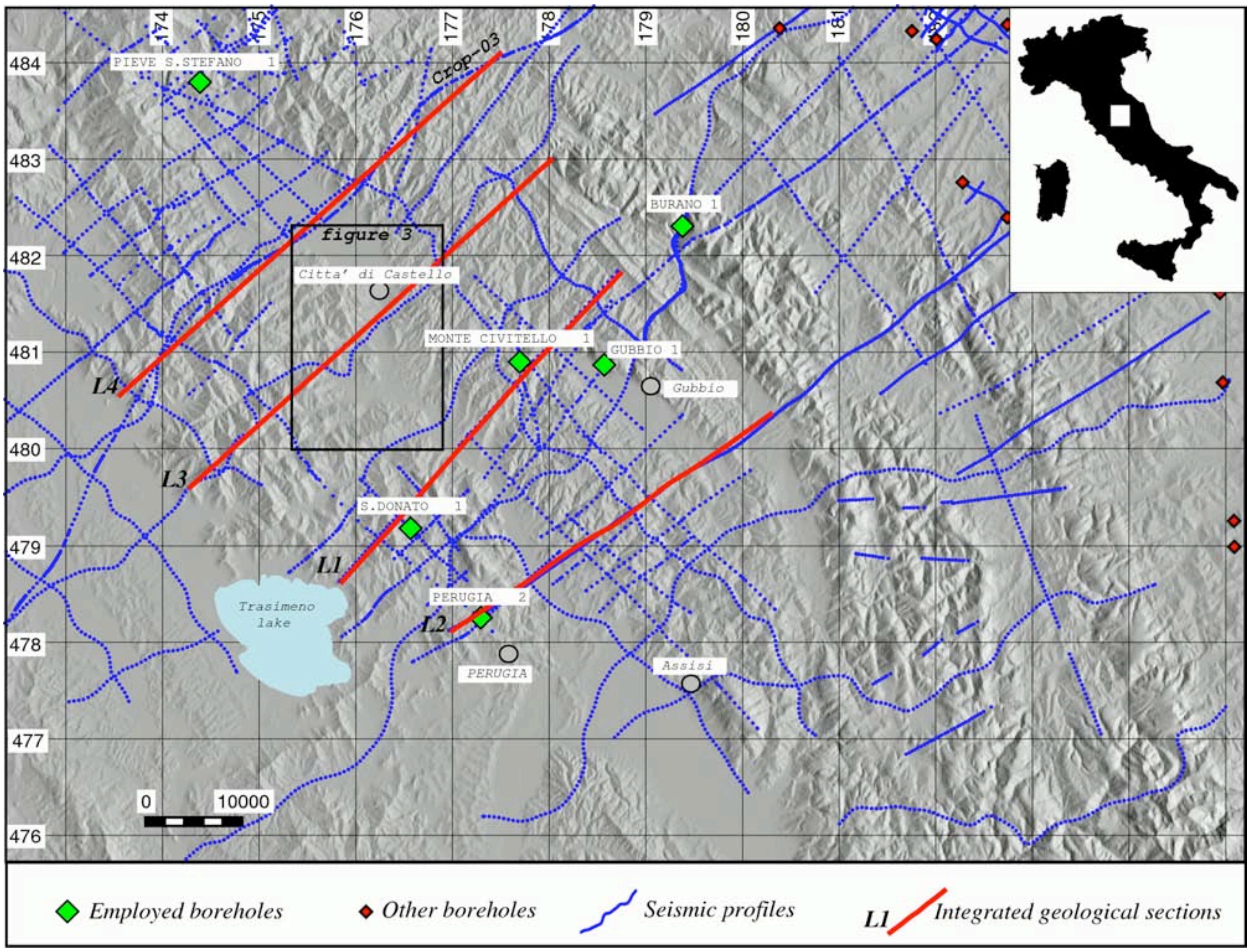


**Figure 1:** Location map of the seismic profiles and boreholes in the ATF area, “Cd” are continental deposits (Quaternary), “mar” are the siliciclastic deposits (middle-late Miocene), “Umc” are the Umbria-Marche carbonates (early Jurassic-middle Miocene), “ev” are the Andriti di Burano fm (middle-late Triassic), “bas” are the basement rocks (permian-middle Triassic), the underlying shaded relief is obtained from the SRTM 90 m resolution DEM available at http://srtm.csi.cgiar.org/index.asp.

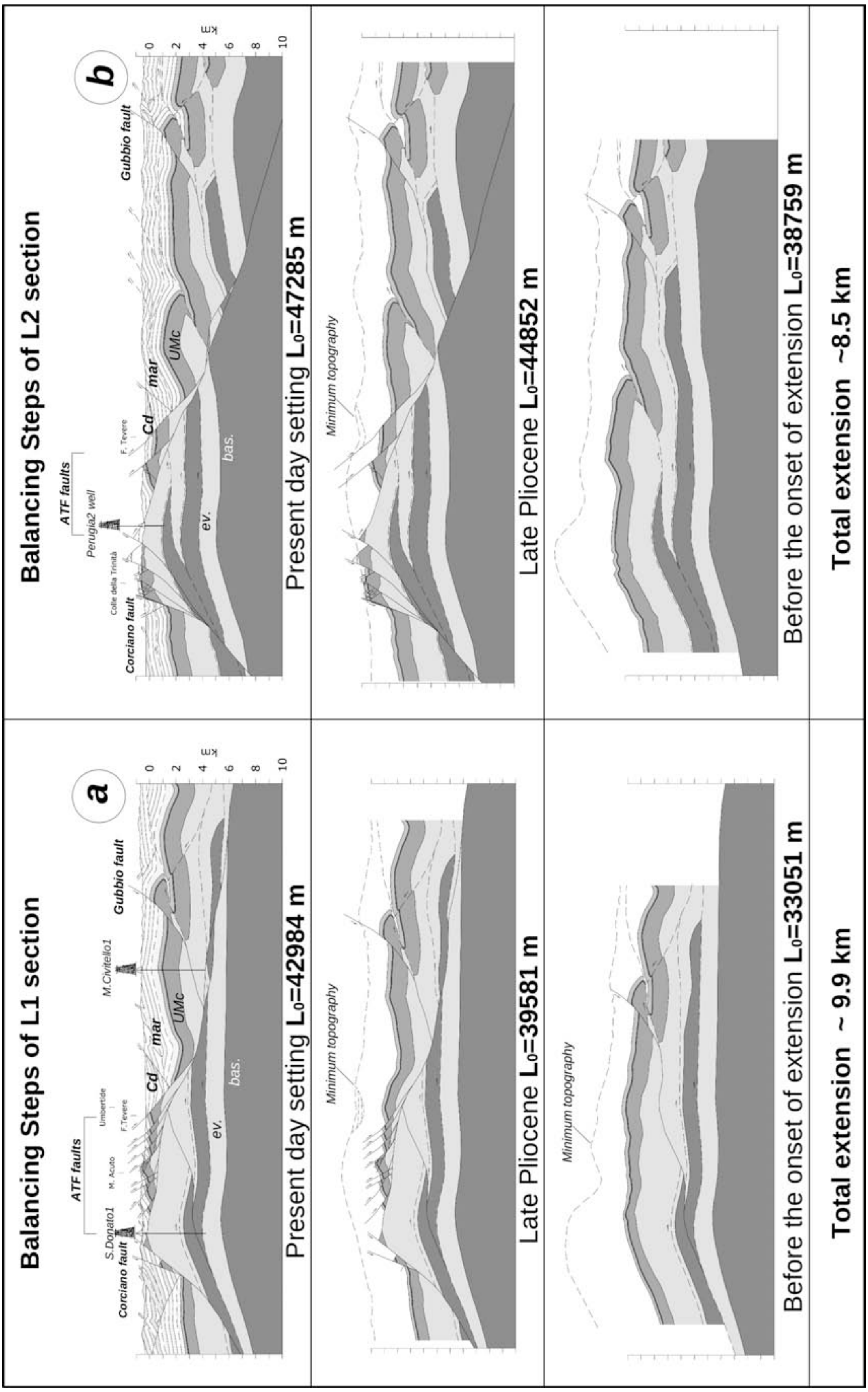


**Figure 2:** Schematic balancing steps of the L1 and L2 sections across the ATF structure and related inferred extensional deformation.

The main topics addressed by this wp concern the coherent re-interpretation of the seismic data, calibration with boreholes and surface geology, estimation of the velocity field through the wells sonic logs for the depth conversion of the reflectors and the sequential restoration of the extensional structures. The data, after being gathered and projected/reprojected into the same geographical reference system with GIS tools, were loaded into the Move$^{TM}$ package which allows the depth conversion and sequential balancing of the geological sections to be made. The sequential restoration and balancing was addressed along two sections (L1 and L2 in figure 1 in D6 deliverable) which cross the region between the Tiber Valley and the Gubbio anticline. The interpretation of these two sections is tied to the stratigraphy of three boreholes, S.Donato1, M.Civitello1 and Perugia2.

**2. Relevance for DPC and/or for the scientific community**

The sections get going in improving the resolution of the geometry of the extensional system giving stronger constrains to compute the cumulative displacement of the ATF and to determine the kinematic interaction between the AT and secondary faults.

**3. Changes with respect to the original plans and reasons for it**

The deliverable was declared for the end of the project.

**4. References**

**5. Key publications/presentation**

*Will follow*

Deliverable D8

Title:  Preliminary Geological and geomorphological map of the High Tiber Valley from Perugia to Città di Castello

*end of phase I*

*prepared by:*
*Task 2 UR3 WP 1.5 Resp. Massimiliano R. Universita' di PG*

# 1. Description of the Deliverable

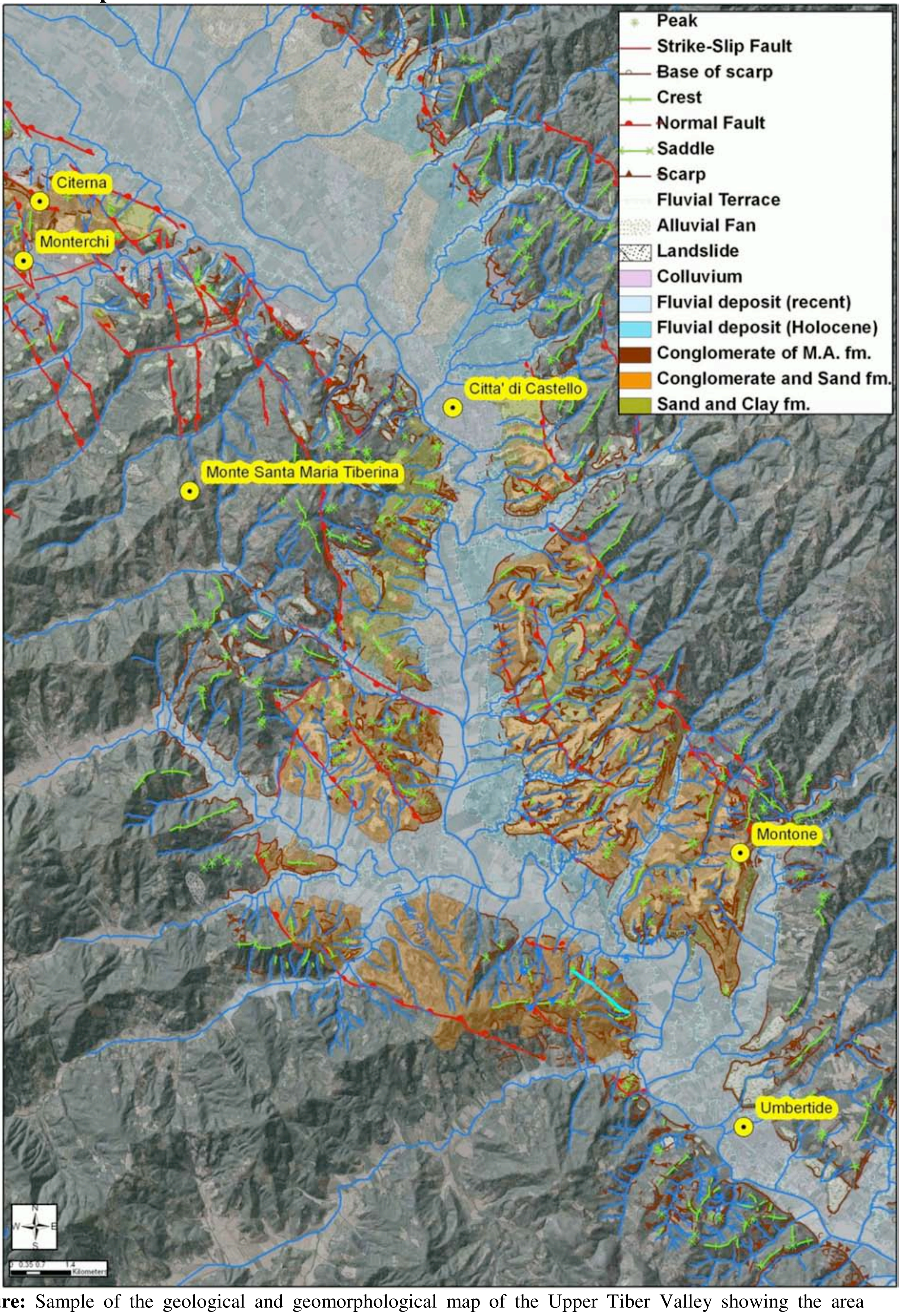


**Figure:** Sample of the geological and geomorphological map of the Upper Tiber Valley showing the area between Città di Castello and Montone. The main geological and geomorphological elements are reported. The underlying shaded relief is obtained from the 10-m-resolution DEM (TinItaly-INGV); the draped image is an orthorectified aerialphotograph (Ministero dell'Ambiente e Tutela del Territorio e del Mare, 2000).

Extensive 1:10,000-scale geological and geomorphological mapping of about 500 $km^2$ along the Upper Tiber Valley, from Sansepolcro to Pierantonio (PG), has been carried out, focussed on the continental deposits infilling the Tiber basin. We started from the existing geological maps, produced in the framework of previous national (CARG) and/or regional (Regione Umbria) projects. The field work was aimed at producing an integrated and homogeneous stratigraphic scheme of the outcropping Early Pleistocene to present deposits, and at characterizing the deposits also from a sedimentological and structural point of view. The geological and geomorphological field mapping was integrated also with other data such as: the observations made on 1:33,000 scale aerial photographs (GAI); 10-m-resolution Digital Elevation Model and standard morphometric derivatives (hill-shaded and slope angle maps, Spatial Analyst™). The mapping was conducted in order to understand the spatial distribution and the paleoenvironmental significance of the deposits associated to the tectonic activity. The map was improved through the reconstruction of the fault system and the deformation pattern affecting the continental deposits (D8). Particular attention was paid to the drainage pattern analysis (strong river incisions, valley profiles, paleodrainages) and to the reconstruction of the Late Pleistocene-Holocene flight of inset terrace surfaces, along with their correlation and ordering, that will be useful for further paleogeodetic analysis. The significant geomorphic features related to the setting of the depositional and tectonic landforms, such as paleosurfaces, scarps, slope changes, crests, peaks, landslides and tectonic lineaments are also drawn.

**2. Relevance for DPC and/or for the scientific community**

We remind you here the importance of the knowledge at local scale (1:10,000) of the thickness and variety of deposits infilling the Tiber basin (from Early Pleistocene to present), to differentiate the site response of the localities along the Tiber Valley.

**3. Changes with respect to the original plans and reasons for it**

The deliverable was declared for the end of the project.

**4. References**

**5. Key publications/presentation**

*Will follow*

Deliverable D11
Title: Preliminary
integrated data bank of continuous
recordings for the period October
2007-October 2009 at the Messina
strait test-site

*end of phase I*

*prepared by:*
*Task 2 UR3 WP 2.2, Resp. Milena Moretti, INGV CNT*

## 1. Description of the Deliverable

The database is the integration of continuous data provided by permanent networks (INGV National Seismic Network; Peloritani Local network, Table 1), temporary deployments (both mobile network from INGV CNT and INGV CT, Table 2) and OBS data (Table 2).

| Sign | Location | Digitizer | Sensor | Net |
|---|---|---|---|---|
| ATN | Antennamare (ME) | PreSys1000 | S-13 | IV |
| CARO | Carosei (CS) | Trident | Trillium 40s /Episensor | IV |
| CEL | Celeste (RC) | Q4120 | STS-2-120S | MN |
| ECPN | Case Del Piano (CT) | Trident | Trillium 40s | I1 |
| ECTS | Castiglione (CT) | Trident | Trillium 40s | I1 |
| ESLN | Serra La Nave (CT) | Trident | Trillium 40s | IV |
| ESPC | Serra Pizzuta (CT) | Trident | Trillium 40s | I1 |
| GIB | Gibilmanna (TP) | Gaia1 | L-4C | IV |
| GIO | Monte San Gregorio (CT) | Gaia2 | L-4C | IV |
| GMB | Gambarie (RC) | Gaia2 | L-4C | IV |
| GRI | Girifalco (CZ) | Gaia1 | L-4C | IV |
| IFIL | Filicudi (ME) | Trident | Le 3d-1s | IV |
| ILLI | Lipari (ME) | Trident | Trillium 40s | IV |
| IVPL | Vulcano Piano (ME) | Trident | Trillium 40s | IV |
| JOPP | Joppolo (VV) | Trident | Trillium 40s | IV |
| MMME | Mongiuffi-Melia (ME) | Trident | Trillium 40s | I1/IV |
| MNO | Monte Soro (ME) | Gaia2 | Le 3d-5s | IV |
| MSCL | Scilla (RC) | Trident | Le 3d-20S | I1 |
| MSRU | Poggio Scudearu (ME) | Trident | Trillium 40s | IV |
| TIP | Timpagrande (KR) | Q4120 | STS-2-120S | MN |
| MILZ | Milazzo Faro (ME) | Gaia2 | Trillium 40s | IV |
| MTTG | Motta San Giovanni (RC) | Trident | Trillium 40s | IV |
| MPAZ | Palizzi (RC) | Trident | Trillium 40s | IV |
| PLAC | Placanica (RC) | Trident | Trillium 40s /Episensor | IV |
| SCLL* | Scilla (RC) | PreSys1000 | S-13 | IV |
| SERS | Sersale (CZ) | Trident | Trillium 40s | IV |
| SLNA* | Salina (ME) | PreSys1000 | S-13 | IV |
| SOI | Samo (RC) | Gaia1 | Le 3d-5s | IV |
| SN1 | Capo Mulini Mare (CT) | CMG-DM24 | CMG-1T-360S | IV |
| STR4 | Stromboli 4 (ME) | Gaia1 | CMG-40T-60S | OV/IV |
| STR5 | Stromboli 5 (ME) | Gaia1 | CMG-40T-60S | IV |

***Table 1** - List of stations of the permanent networks included in the database (MN =MedNet, Mediterranean Very Broadband Seismographic; IV = Italian Seismic Network; I1 INGV-CT Seismic Network; OV = INGV - Osservatorio Vesuviano ).*

| Sign | Location | IN/OUT | Digitizer | Sensor | Net |
|---|---|---|---|---|---|
| ME01 | Mistretta (ME) | 18.10.07/03.02.09 | Reftek130 | Le 3d-5s | TN |
| ME02 | San Fratello (ME) | 19.10.07/03.02.09 | Reftek130 | Le 3d-5s | TN |
| ME03 | Palmi (RC) | 20.10.07/----------- | Reftek130 | Le 3d-5s | TN |
| ME04 | Brognaturo (VV) | 21.10.07/29.06.08 | Reftek130 | Le 3d-5s | TN |
| ME05 | Diga Del Menta (RC) | 22.10.07/----------- | Reftek130 | Le 3d-5s | TN |
| ME06 | Antenna a Mare (ME) | 15.11.07/13.05.08 | Reftek130 | Le 3d-5s | TN |
| ME07 | Castell'Umberto (ME) | 22.11.07/13.05.08 | Reftek130 | Le 3d-5s | TN |
| ME08 | Mali (ME) | 08.11.07/----------- | Reftek130 | Le 3d-5s | TN |
| ME09 | Pentodattilo (RC) | 08.11.07/----------- | Reftek130 | Le 3d-5s | TN |
| ME10 | Cittanova (RC) | 22.11.07/05.02.09 | Reftek130 | Le 3d-5s | TN |
| ME11 | Novara di Sicilia (ME) | 15.11.07/----------- | Taurus | Le 3d-20s | TN |
| ME12 | Panarea (ME) | 06.11.07/----------- | Taurus | Le 3d-20s | TN |
| ME13 | Scilla (RC) | 08.11.07/08.12.07 | Taurus | Le 3d-20s | TN |
| ME14 | Gambarie (RC) | 08.11.07/---------- | Taurus | Le 3d-20s | TN |
| ME15 | Gioiosa Marea | 18.10.07/---------- | Reftek130 | Le 3d-5s | TN |
| ME16 | Antenna a Mare (ME) | 01.09.08/07.02.09 | Reftek130 | Le 3d-5s | TN |
| A2 | South of Strait of Messina | 15.0708/07.11.08 | Geolon MLS | Trillium120p | OBSt |
| A3 | North of Strait of Messina | 18.0708/07.11.08 | Geolon MLS | Trillium120p | OBSt |
| A4 | South of Strait of Messina | 15.0708/07.11.08 | Geolon MLS | Trillium120p | OBSt |
| A5 | North of Strait of Messina | 18.0708/07.11.08 | Geolon MLS | Trillium120p | OBSt |
| A6 | North of Strait of Messina | 18.0708/07.11.08 | Geolon MLS | Trillium120p | OBSn |

**Table 1 -** *List of stations of the temporary network (TN =Network Temporary; OBSt = OBS network) .*

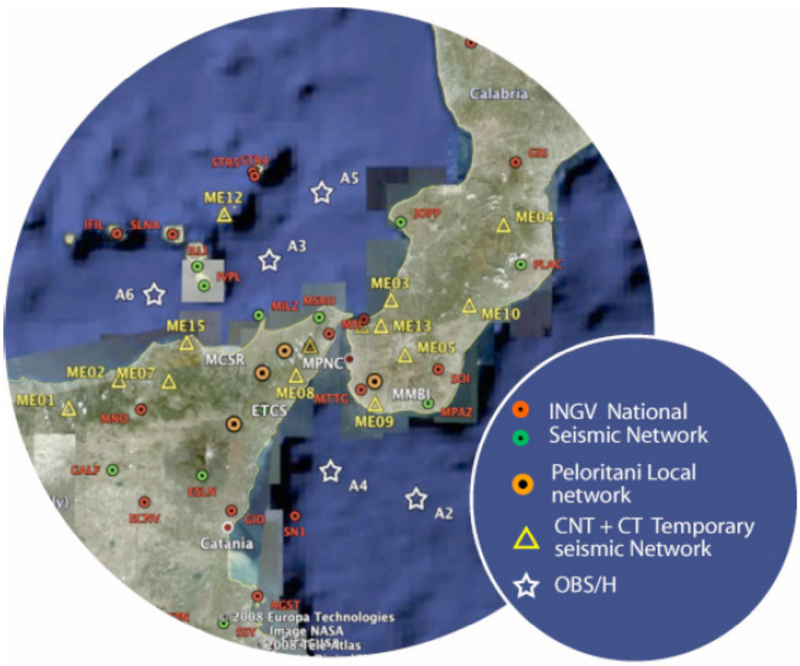


**Figure 1** - *The map of the seismic network.*

In the figures 2 and 3, are shown the details of the operation of the temporary network, mobile network  and OBS, respectively.

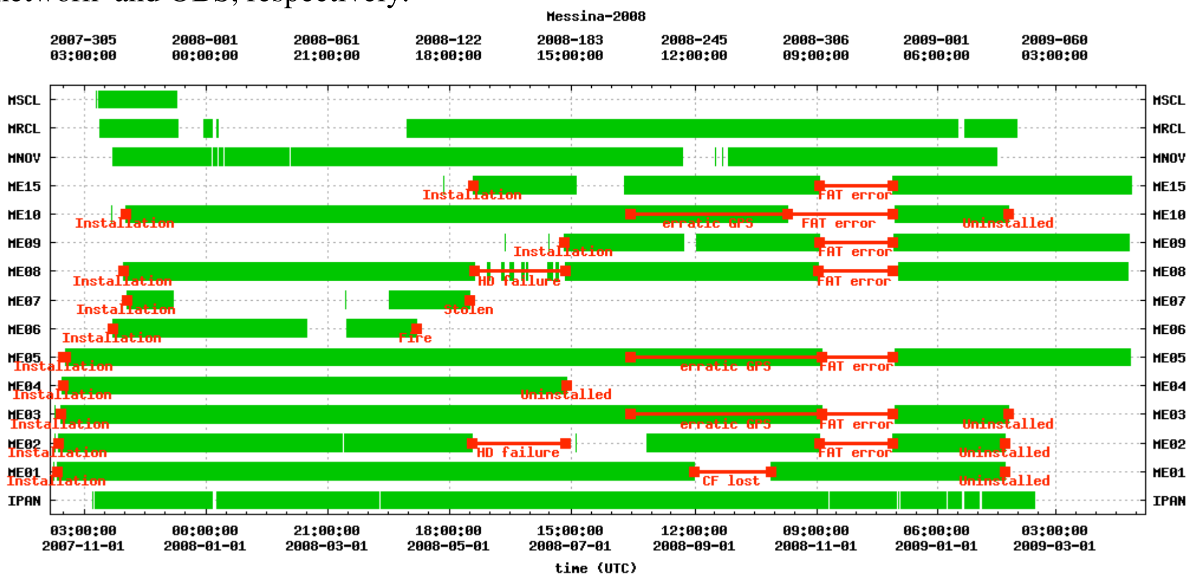


**Figure 2** - *Seismic network data available.*

| Year | 2008 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | July | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Julian day | 183 | 184 | 185 | 186 | 187 | 188 | 189 | 190 | 191 | 192 | 193 | 194 | 195 | 196 | 197 | 198 | 199 | 200 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 | 211 | 212 | 213 |
| OBS A2 | | | | | | | | | | | | | | | D | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| OBS A3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| OBS A4 | | | | | | | | | | | | | | | D | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| OBS A5 | | | | | | | | | | | | | | | | | | D | X | X | X | X | X | X | X | X | X | X | X | X | X |
| OBS A6 | | | | | | | | | | | | | | | | | | D | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Day | August | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Julian day | 214 | 215 | 216 | 217 | 218 | 219 | 220 | 221 | 222 | 223 | 224 | 225 | 226 | 227 | 228 | 229 | 230 | 231 | 232 | 233 | 234 | 235 | 236 | 237 | 238 | 239 | 240 | 241 | 242 | 243 | 244 |
| OBS A2 | X | X | X | X | X | X | X | X | X | I | I | I | I | I | I | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O |
| OBS A3 | | D | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| OBS A4 | S | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I |
| OBS A5 | X | X | X | X | X | X | X | X | X | X | X | I | I | I | I | I | I | I | O | O | O | O | O | O | O | O | O | O | O | O | O |
| OBS A6 | X | X | X | X | X | X | X | X | X | X | I | I | I | I | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O |
| Day | September | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | |
| Julian day | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 | 261 | 262 | 263 | 264 | 265 | 266 | 267 | 268 | 269 | 270 | 271 | 272 | 273 | 274 | |
| OBS A2 | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | |
| OBS A3 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | |
| OBS A4 | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | |
| OBS A5 | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | |
| OBS A6 | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | |
| Day | October | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Julian day | 275 | 276 | 277 | 278 | 279 | 280 | 281 | 282 | 283 | 284 | 285 | 286 | 287 | 288 | 289 | 290 | 291 | 292 | 293 | 294 | 295 | 296 | 297 | 298 | 299 | 300 | 301 | 302 | 302 | 304 | 305 |
| OBS A2 | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | I | I | I | I | I | I | I | I | I | I |
| OBS A3 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| OBS A4 | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | R | | | | | | | | | | | | | |
| OBS A5 | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O |
| OBS A6 | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O |
| Day | November | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | |
| Julian day | 306 | 307 | 308 | 309 | 310 | 311 | 312 | 313 | 314 | 315 | 316 | 317 | 318 | 319 | 320 | 321 | 322 | 323 | 324 | 325 | 326 | 327 | 328 | 329 | 330 | 331 | 332 | 333 | 324 | 335 | |
| OBS A2 | I | I | I | I | I | I | I | R | | | | | | | | | | | | | | | | | | | | | | | |
| OBS A3 | X | X | X | X | X | X | R | | | | | | | | | | | | | | | | | | | | | | | | |
| OBS A4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| OBS A5 | O | O | O | O | O | R | | | | | | | | | | | | | | | | | | | | | | | | | |
| OBS A6 | O | O | O | O | O | O | R | | | | | | | | | | | | | | | | | | | | | | | | |

**D** deployment/start acquisition  **S** operating (Seismometer only)
**R** Recovery/stop acquisition  **O** operating (DPG only )
**X** operating (Velocimeter + DPG)  **I** inaccurate recording, so that data cannot be used

***Figure  3*** - *OBS data available.*

To build the archive, we are converting all the continuous seismic recordings (permanent stations, temporary stations and OBS) to a uniform format (SEED). To achieve this goal, the INGV CNT, INGV Catania and INGV Napoli data centers have been connected in real time via seedlink to gather the waveforms from the Peloritani and Eolian Islands Networks.
Simultaneously, the temporary stations have been deployed on November 2007 and the data has been collected on a regular basis and the OBS deployment was realized between July and November 2008.
The data is stored in the original format on the mobile network data server MAYA, then it is going to be converted to SEED data format and fed to the HSL seedlink/arclink server. The data from permanent networks is stored in HSL together with RSN data and is accessible in real-time for 15 days (Figure 4).

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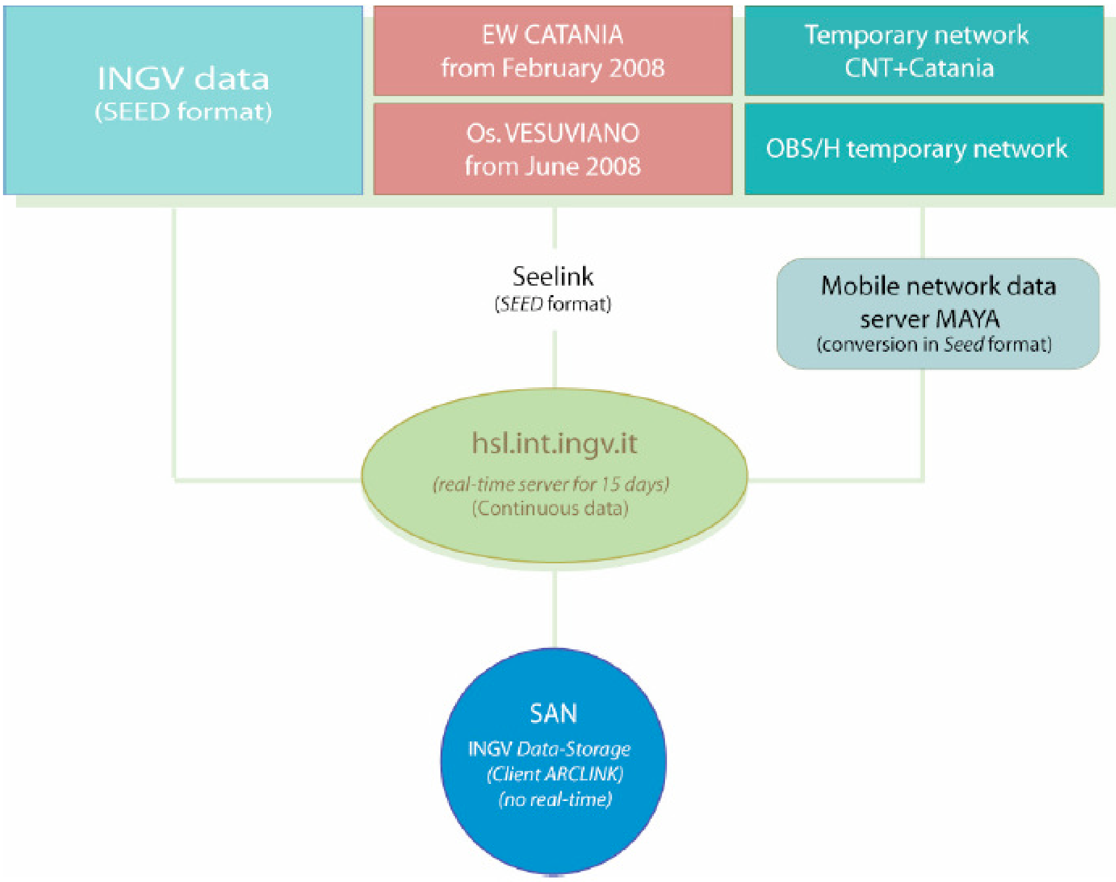



***Figure 4*** *- Schetch of the data sources and the role of the data servers in the process of archive building.*

After this period the data is moved to the CNT SAN and can be retrieved through the arclink interface http://hgp2.int.ingv.it/arclink/query (Figure5) . Up to now only stations from permanent network are in the Seed –archive.

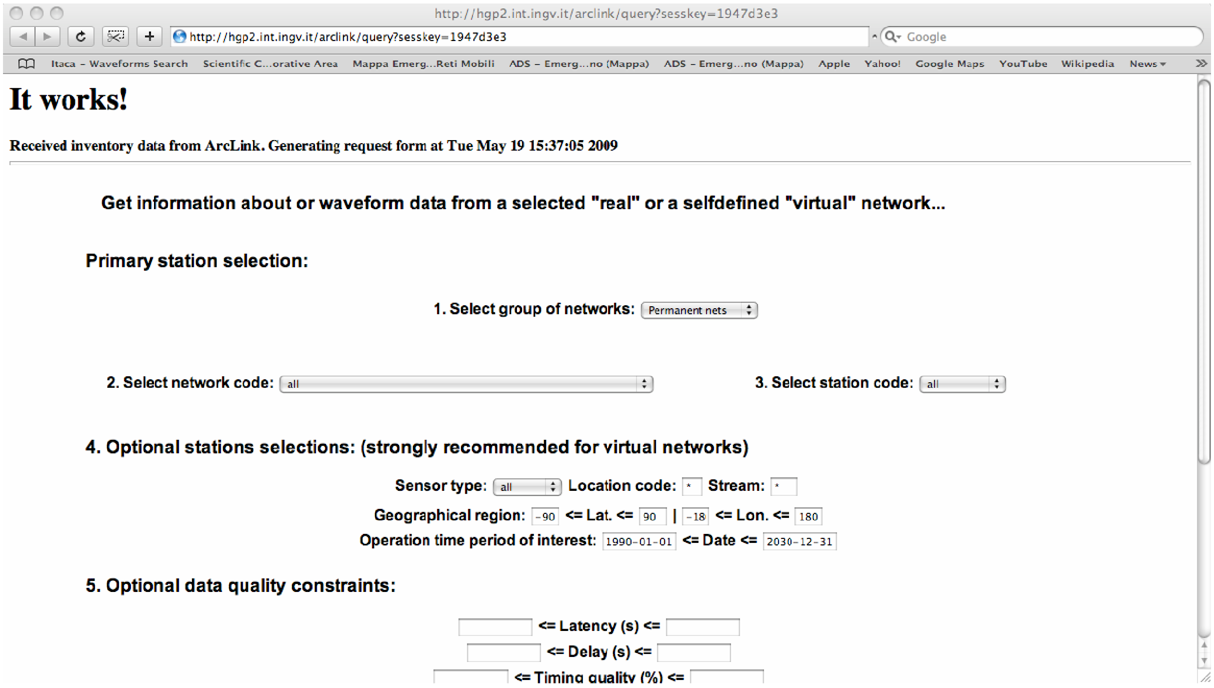


*Figure 5* *Arclink interface*

## 2. Relevance for DPC and/or for the scientific community

The existence of a data base of continuous seismic recordings which include permanent seismic network and temporary deployment is fundamental for the study and comprehension of the Italian seismicity; hopefully integrated database will become a standard for INGV seismic experiment, as Messina 1908-2008, and for deployments relative to seismic emergency, as L'Aquila.

## 3. Changes with respect to the original plans and reasons for it

The database is in a preliminary stage

## 4. References

## 5. Key publications/presentation

*will follow*

Deliverable D12
Title: Preliminary earthquakes locations in the Tyrrhenian and Ionian regions around Messina Strait to define seismogenic structures

*end of phase I*

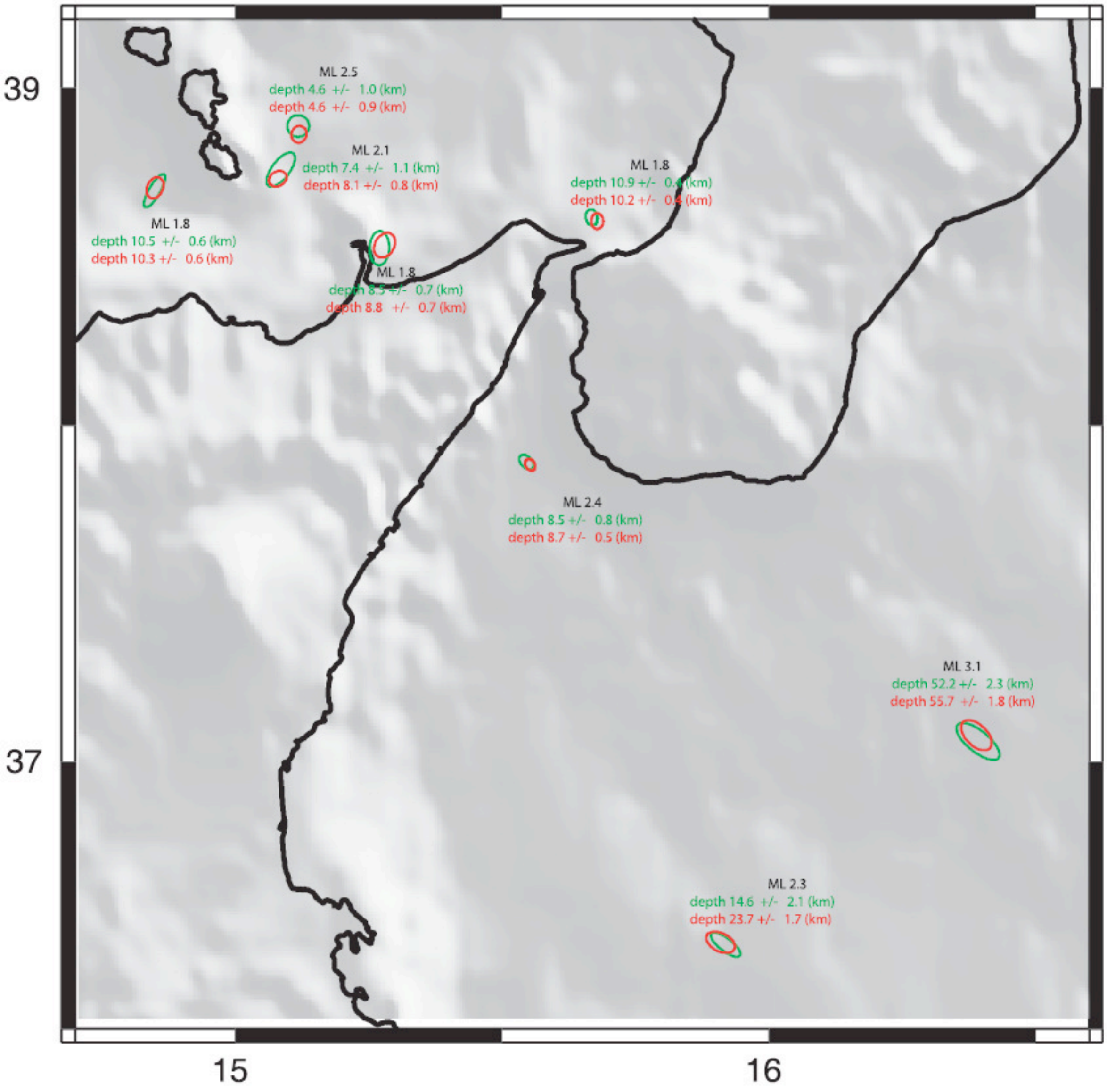
*prepared by:*
*Task 2 UR3 WP 2.2, Resp. Milena Moretti, INGV CNT*

## 1. Description of the Deliverable

The event detection and location is not yet at the expected stage. Once the data set of D11 is ready we will evaluate the improvement introduced by the use of OBS on the seismic detection and on the earthquake location and we will compute refined hypocentral locations to define seismogenetic structures inside the Messina Strait and in the surrounding region especially in the Tyrrhenian and Ionian sea.
Using continuous recordings of the integrated network a semiautomatic procedure (WP1.1) will define the triggers and the P and S arrivals to locate the seismicity using both conventional and refined techniques. This automatic stage can be reviewed by the seismologist using the standard tools of the National Network ("SisPick2" [Bono, 2008] for picking and "Locator" [Basili] for hypocentral location, both this tools have been tailored for this task).
We are still working on the database of the continuous recordings of the integrated network so we did not apply the semi automatic procedure which defines triggers and P and S pickings (see WP1 of the Alto Tiberina fault task) so we do not know how much we lowered the magnitude detection level with the deployment of land and OBS temporary stations.
To verify the improvement that the Messina 1908-2008 seismic deployment can introduce on locations of the National Seismic network we performed a location exercise. We extracted 8 events recorded at Messina1908-2008 integrated network and compared locations done using only the National seismic Network and the Integrated Networks (including OBS). Epicenters move very little but we observe a moderate decrease of uncertainty in the hypocentral parameters and a change in the depth of the events located in the Ionian sea.

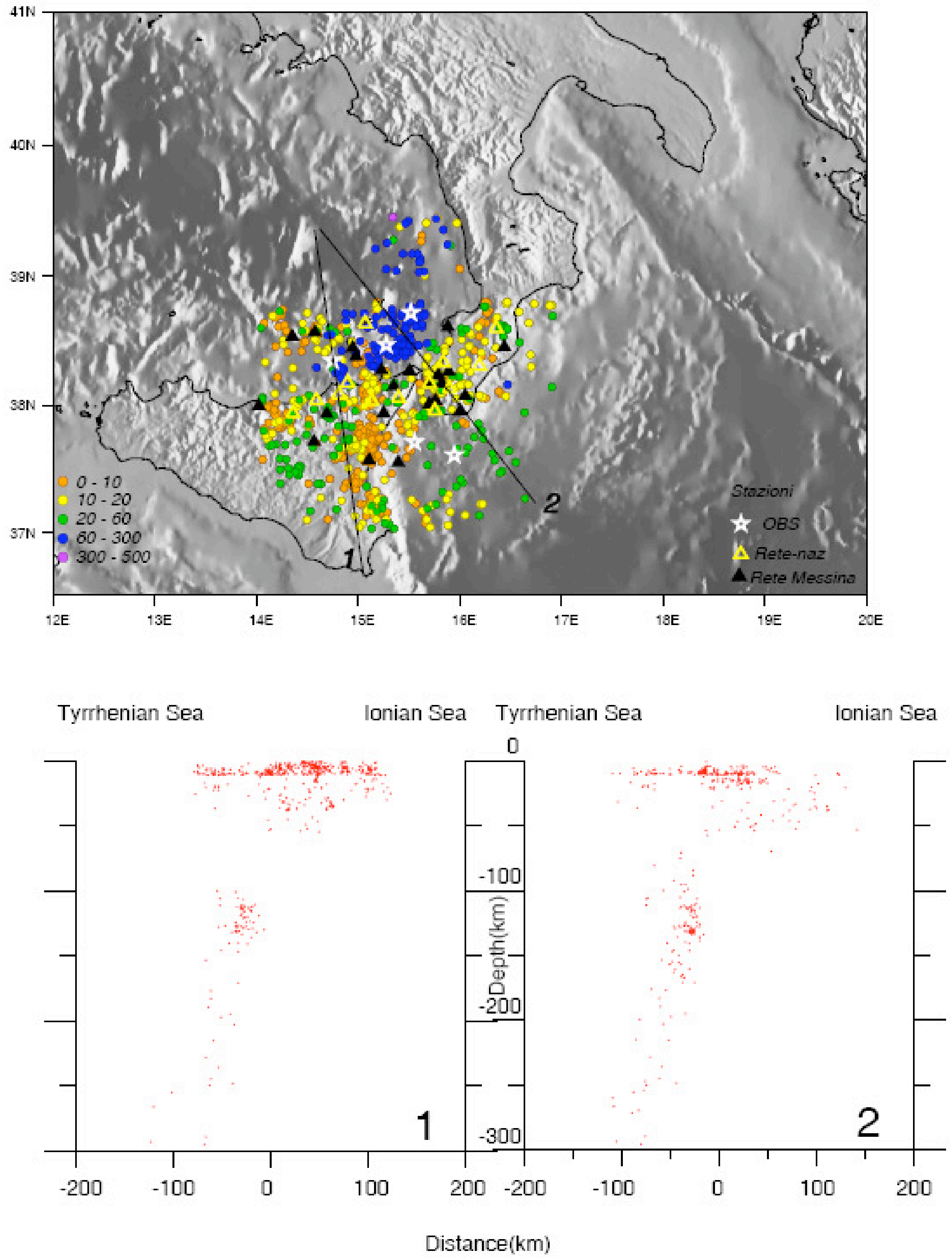
| **Only** | **National** | | **Network** | | | | |
|---|---|---|---|---|---|---|---|
| lon | lat | depth | Az (°) main axis-ellipse | herrmax | herrmin | zerr | Ml |
| 15.1178 | 38.4428 | 4.6 | 4 | 0.89 | 0.89 | 1.0 | 2.6 |
| 15.6649 | 38.3107 | 8.5 | 170 | 0.49 | 0.36 | 0.7 | 1.8 |
| 15.9188 | 37.2261 | 10.9 | 128 | 1.48 | 0.53 | 0.4 | 2.3 |
| 15.0853 | 38.3786 | 7.4 | 37 | 1.66 | 0.72 | 1.1 | 2.1 |
| 16.3917 | 37.5301 | 52.2 | 129 | 2.18 | 0.88 | 2.3 | 3.1 |
| 15.5455 | 37.9458 | 8.5 | 135 | 0.72 | 0.45 | 0.8 | 2. 4 |
| 15.2702 | 38.2625 | 14.6 | 1 | 1.40 | 0.80 | 2.1 | 1.9 |
| 14.8488 | 38.3474 | 10.5 | 30 | 1.54 | 0.46 | 0.6 | 1.8 |

| **Integrated** | **Network** | | | | | | |
|---|---|---|---|---|---|---|---|
| lon | lat | depth | Az (°) main axis-ellipse | herrmax | herrmin | zerr | Ml |
| 15.1194 | 38.4306 | 4.6 | 16 | 0.69 | 0.61 | 0.9 | 2.6 |
| 15.6781 | 38.3024 | 8.8 | 0 | 0.65 | 0.49 | 0.7 | 1.8 |
| 15.9093 | 37.2298 | 10.2 | 117 | 1.27 | 0.76 | 0.4 | 2.3 |
| 15.0796 | 38.3650 | 8.1 | 61 | 0.76 | 0.59 | 0.8 | 2.1 |
| 16.3887 | 37.5394 | 55.7 | 134 | 1.54 | 0.88 | 1.8 | 3.1 |
| 15.5525 | 37.9418 | 8.7 | 149 | 0.51 | 0.38 | 0.5 | 2. 4 |
| 15.2798 | 38.2669 | 23.7 | 30 | 1.08 | 0.79 | 1.7 | 1.9 |
| 14.8496 | 38.3517 | 10.3 | 24 | 0.91 | 0.64 | 0.6 | 1.8 |




*Locations, for 8 sample events recorded in August 2008, done using the Seismic National Network in green and in red the locations done using the land-sea integrated Messina 1908-2008 network. Formal errors in the locations decrease. The deployment of the temporary stations and OBS almost double the number of stations that can be used to locate events.*

These results testify for the good quality of the INGV Bulletin location http://iside.rm.ingv.it/iside/standard/index.jsp. Here you find enclosed a map and cross-sections (and in a separated file the locations) of events recorded by the National Seismic Network in the period of the deployment. This list is being extracted from the recordings of the temporary 1908-2008 stations in sac format to be preliminary analyzed: the largest events should be exchanged with UR04 for the focal mechanisms computation.




*November 2007-April 2009 events located by the Italian seismic Network and cut in sac format at the temporary stations*

## 2. Relevance for DPC and/or for the scientific community

Refined locations in the area of seismicity and microseismicity recorded will delineate the presence of seismogenic structures in the study area which will help in understanding the seismotectonics of the area.

## 3. Changes with respect to the original plans and reasons for it

The event detection and location is not yet at the expected stage but the occurrence of the Mw 6.3 earthquake near L'Aquila on April the $6^{th}$ introduced a new priority in the working program of the INGV staff. The seismic emergency benefit of the work done in S5 and in the WP2.2 but the work planned was indeed delayed.

## 4. References

## 5. Key publications/presentation

*[following the completion of this deliverable]*

Deliverable D16

Title: Database of focal mechanisms of earthquakes in the Messina Straits over the time period between 1988 and 2007

*end of phase I*

*prepared by:*
*Task 2 UR04 WP 2.6, Resp. Giancarlo Neri*

## 1. Description of the Deliverable

Database of selected focal mechanisms of earthquakes in the Messina Straits over the time period between 1988 and 2008 before the starting of the Messina 1908-2008 deployment.

| date | O.T. | lat (°N) | lon (°E) | dep (km) | Ml | Strike | Dip | rake |
|---|---|---|---|---|---|---|---|---|
| 1988.04.11 | 1:50 | 38.12 | 15.12 | 12.0 | 2.6 | 46 | 58 | -56 |
| 1988.06.10 | 1:31 | 38.19 | 15.16 | 9.1 | 2.6 | 120 | 50 | -80 |
| 1988.11.07 | 14:26 | 38.09 | 15.84 | 16.4 | 3.4 | 200 | 85 | 80 |
| 1988.11.08 | 7:02 | 38.07 | 15.84 | 15.7 | 2.4 | 30 | 30 | 10 |
| 1988.11.08 | 8:13 | 38.13 | 15.86 | 21.6 | 2.9 | 60 | 65 | -30 |
| 1989.01.23 | 8:22 | 37.86 | 15.51 | 21.5 | 3.0 | 160 | 5 | 40 |
| 1989.05.26 | 22:19 | 38.16 | 15.11 | 14.9 | 3.1 | 340 | 50 | -170 |
| 1989.06.21 | 16:46 | 38.18 | 15.03 | 12.0 | 2.8 | 120 | 76 | 90 |
| 1989.11.21 | 18:36 | 38.12 | 15.90 | 10.4 | 3.8 | 40 | 35 | -130 |
| 1990.04.04 | 15:03 | 38.22 | 15.07 | 10.4 | 2.6 | 35 | 65 | -60 |
| 1990.05.10 | 6:47 | 38.25 | 15.51 | 21.5 | 3 | 0 | 55 | 111 |
| 1990.09.15 | 3:11 | 38.08 | 15.85 | 14.7 | 3.0 | 10 | 60 | -80 |
| 1990.12.18 | 17:49 | 38.14 | 15.15 | 13.4 | 3 | 30 | 55 | -111 |
| 1991.09.07 | 5:39 | 37.96 | 15.50 | 8.4 | 3.2 | 20 | 85 | -160 |
| 1991.09.25 | 13:21 | 38.02 | 15.98 | 7.9 | 3.3 | 350 | 40 | -130 |
| 1991.09.25 | 14:53 | 37.98 | 16.03 | 10.4 | 3.5 | 340 | 50 | -130 |
| 1991.09.25 | 21:21 | 37.98 | 16.02 | 8.9 | 3.4 | 15 | 40 | -130 |
| 1992.05.03 | 1:30 | 38.18 | 15.22 | 17.0 | 3 | 45 | 70 | -59 |
| 1992.06.28 | 6:03 | 38.33 | 15.80 | 14.2 | 3.3 | 110 | 80 | 10 |
| 1993.08.24 | 1:20 | 38.13 | 15.13 | 14.1 | 3 | 140 | 50 | -80 |
| 1993.12.05 | 19:18 | 37.81 | 15.04 | 15.3 | 2.5 | 20 | 30 | -31 |
| 1993.12.05 | 19:32 | 37.81 | 15.04 | 15.4 | 2.9 | 5 | 50 | 80 |
| 1993.12.13 | 18:09 | 37.81 | 15.04 | 15.3 | 2.7 | 350 | 25 | 12 |
| 1994.05.10 | 17:55 | 37.83 | 15.03 | 17.7 | 2.7 | 115 | 30 | -180 |
| 1994.07.03 | 7:05 | 38.32 | 15.14 | 28.6 | 3 | 90 | 65 | 79 |
| 1994.07.06 | 13:29 | 37.87 | 15.01 | 6.2 | 3.1 | 165 | 30 | -70 |
| 1994.07.23 | 20:57 | 38.13 | 15.18 | 10.5 | 2.7 | 105 | 40 | 150 |
| 1994.08.19 | 1:51 | 37.95 | 15.82 | 15.9 | 3.0 | 110 | 50 | -80 |
| 1994.10.01 | 22:37 | 38.48 | 15.10 | 11.2 | 3.2 | 85 | 75 | 130 |
| 1995.07.24 | 16:58 | 37.98 | 15.40 | 11.4 | 3.7 | 155 | 55 | -50 |
| 1995.08.03 | 12:15 | 37.80 | 15.55 | 3.5 | 2.9 | 75 | 5 | -37 |
| 1995.08.27 | 19:42 | 38.28 | 15.17 | 8.9 | 4 | 225 | 85 | 0 |
| 2000.02.08 | 22:19 | 37.88 | 15.57 | 26.0 | 2.6 | 205 | 45 | -30 |
| 2000.03.08 | 9:38 | 38.23 | 15.75 | 13.3 | 3.0 | 50 | 30 | -150 |
| 2000.03.17 | 3:52 | 37.98 | 15.94 | 9.3 | 3.8 | 115 | 65 | -80 |
| 2000.03.17 | 6:35 | 37.97 | 15.93 | 10.9 | 3.3 | 85 | 65 | -90 |
| 2000.05.29 | 14:25 | 38.15 | 15.12 | 9.0 | 3 | 5 | 55 | -130 |
| 2004.10.11 | 7:31:41 | 37.88 | 15.48 | 6.6 | 3.5 | 89 | 90 | -45 |
| 2004.10.22 | 21:10:13 | 38.08 | 15.32 | 10.7 | 3.5 | 78 | 61 | -37 |
| 2005.04.19 | 22:36:23 | 38.14 | 15.66 | 7.1 | 3.2 | 220 | 42 | -10 |
| 2005.04.23 | 19:10:48 | 38.43 | 15.82 | 13.6 | 3.0 | 120 | 50 | -64 |
| 2005.08.14 | 22:02:27 | 37.80 | 15.12 | 6.7 | 3.0 | 82 | 50 | -18 |
| 2006.02.27 | 4:34:01 | 38.10 | 15.17 | 10.1 | 4.1 | 62 | 50 | -71 |
| 2006.02.27 | 9:11:59 | 38.14 | 15.18 | 10.5 | 3.5 | 39 | 48 | -90 |
| 2006.02.27 | 14:16:06 | 38.14 | 15.18 | 9.1 | 3.3 | 76 | 48 | -58 |
| 2006.07.02 | 17:52:00 | 38.13 | 15.10 | 10.0 | 3.0 | 70 | 59 | -49 |
| 2006.07.18 | 7:42:40 | 38.12 | 15.17 | 9.1 | 3.3 | 90 | 41 | -49 |
| 2006.10.06 | 21:16:23 | 38.10 | 15.57 | 9.6 | 3.2 | 18 | 52 | -90 |
| 2006.11.04 | 5:59:22 | 38.03 | 15.01 | 10.6 | 3.1 | 59 | 49 | -37 |
| 2007.06.17 | 12:11:58 | 38.37 | 15.79 | 10.0 | 3.3 | 262 | 38 | -43 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2007.08.18 | 14:04:07 | 38.23 | 15.13 | 9.4 | 4.0 | 44 | 50 | -23 |
| 2007.08.18 | 14:21:11 | 38.19 | 15.12 | 10.0 | 3.2 | 26 | 69 | 18 |
| 2008.02.09 | 7:46:36 | 37.84 | 15.56 | 6.9 | 3.1 | 40 | 90 | -10 |
| 2008.04.13 | 13:06:57 | 38.25 | 15.70 | 14.3 | 3.3 | 6 | 51 | -30 |
| 2008.05.01 | 21:05:49 | 37.80 | 15.07 | 2.0 | 3.4 | 96 | 76 | 2 |
| 2008.05.13 | 21:28:30 | 37.80 | 15.06 | 12.0 | 3.3 | 76 | 46 | -20 |
| 2008.07.05 | 17:04:36 | 38.20 | 15.87 | 10.0 | 3.0 | 311 | 59 | 2 |
| 2008.09.01 | 14:45:40 | 37.97 | 15.06 | 8.1 | 3.1 | 70 | 31 | -80 |
| 2008.09.02 | 9:16:45 | 37.99 | 15.06 | 10.3 | 3.4 | 279 | 64 | -44 |
| 2008.10.27 | 10:55:55 | 38.11 | 15.13 | 2.0 | 4.0 | 50 | 28 | -71 |

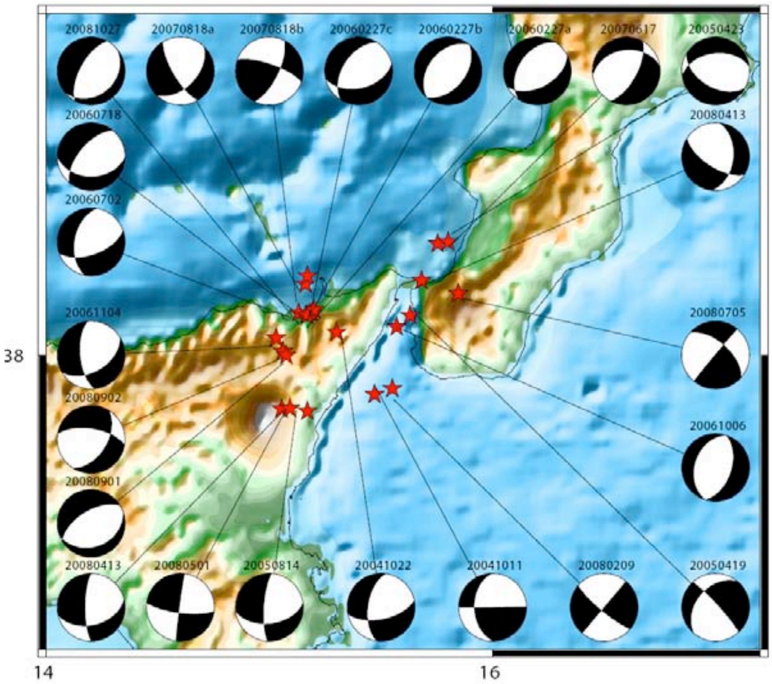



**Figure** Focal mechanisms computed with the CAP method.

## 2. Relevance for DPC and/or for the scientific community

Its an important contribution to define the seismic deformation of the Messina Strait area

## 3. Changes with respect to the original plans and reasons for it

None

## 4. References

## 5. Key publications/presentation

D'Amico, S., Orecchio, B., Presti, D., Zhu, L., Herrmann, R. B., Neri, G., 2009. Moment tensor solutions of recent earthquakes in the Messina Straits area, southern Italy. Abstract presented at the Seismological Society of America, Annual Meeting Monterey, CA, (USA), April 8 - 11 2009.

D'Amico, S., Orecchio, B., Presti, D., Zhu, L., Herrmann, R. B., Neri, G., 2008. Moment Tensor Solutions in the Area of the 1908 Messina Earthquake: Preliminary Results. Abstract presented at the 1908 – 2008: Scienza e Società a 100 anni dal grande Terremoto Conference, Reggio Calabria (Italy), December 10-12 2008.

# Deliverable D20
# Title: Preliminary re-picking arrival time catalogue and earthquake locations (Irpinia test-site)

*end of phase I*

*prepared by:*
*Task 3 UR6 WP 3.2, Resp Claudio Satriano, Università di Napoli Federico II and AMRA scarl*

## 1. Description of the Deliverable

### *1.1 Description of the data-set*

We performed an accurate manual re-picking of local earthquakes recorded at the ISNet and the nearby INGV stations in the period 2005/08/22 – 2008/09/28. The number of events is 640 (44703 traces), for a total number of 4705 P picks and 2916 S picks.

A first evaluation of picking consistency has been performed analyzing the modified Wadati diagram (Chatelain, 1978), which also provides an estimate of Vp/Vs of 1.87.
Then, picking quality has been assessed performing a preliminary location and looking, for each station, at outliers on the histograms of residuals. The 1D velocity model used for location has been constructed as a 3-gradient model, visually averaging several models of the area available in literature (fig. 1). For all the analyses we used the NonLinLoc location code (Lomax et al., 2000; Lomax and Curtis, 2001).

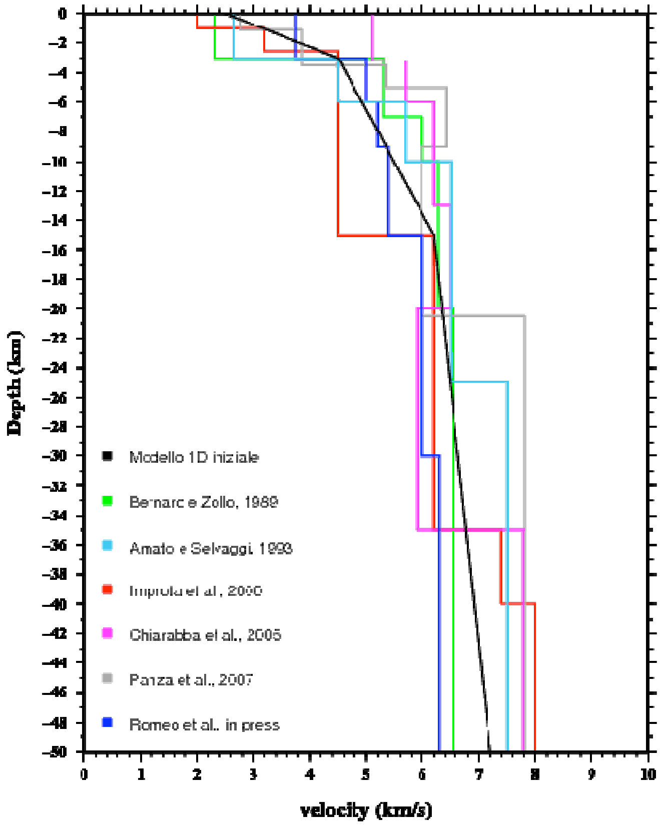



**Figure 1** P-wave velocity models for the Irpinia region available in literature (colored lines) and 1D 3-gradient velocity model computed by visual averaging (black line).

Starting from the original set of 640 events, we selected a subset of 230 well-constrained earthquakes: we located all the events using all the velocity models, and we chose only the earthquakes whose epicentral location and depth do not change more than 5 km and 15 km, respectively. The resulting data set is shown in figure 2, where the location is preformed using the 1D 3-gradient model.

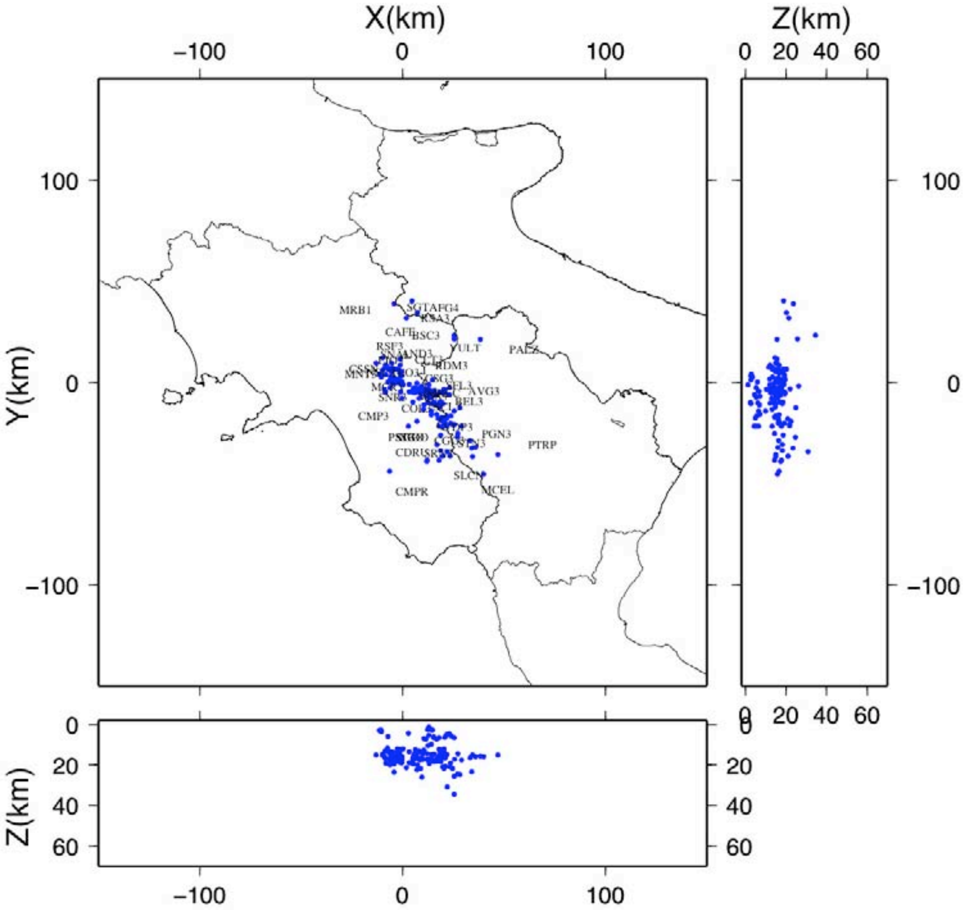



**Figure 2** Subset of 230 well-constrained earthquakes, located using the 1D 3-gradient velocity model shown in figure 1. Both ISNet and nearby INGV stations (displayed in the figure) have been used for the analysis.

We deliver the selected 230 events as a preliminary version of the catalogue of high-quality arrival times and earthquake locations for the seismicity recorded at the Irpinia test-site.

*1.2 File format*

The catalogue is delivered as a tgz archive (D20_preliminary.tgz), containing 4 files:

- `D20-prel-events.pun`
  This file contains locations for the selected 230 earthquakes, in hypo71 format. Each line corresponds to an event.
  Please refer to the attached hypo71 manual, section 3.2 for an explanation of the file format.
  Events are located using NonLinLoc in the 1D 3-gradient velocity model.

- `D20-prel-phases_ev.hypo`
  This file contains all the P and S phase readings performed on the ISNet and INGV stations for the selected 230 earthquakes. The file has the hypo71 format. Phase readings for each event are separated by a line where depth, latitude and longitude of the event are specified.
  Please refer to the attached hypo71 manual, sections 2.2-9, 2.2-10 and 2.2-11 for an explanation of the file format.

- `stations.dat`
  Contains the coordinates (lat, lon, elevation (km)) of the stations used for this study.

- `hypo71manual.pdf`
  The hypo71 manual (USGS open file report 75-311)

**2. Relevance for DPC and/or for the scientific community**

This deliverable provides a set of very well constrained earthquakes which will be further extended, yielding to a high resolution picture of the active fault systems at the Irpinia test site.

An accurate catalog of phase readings and earthquake locations is the necessary starting point for every detailed study of the crustal structure of the area.

**3. Changes with respect to the original plans and reasons for it**

N/A

**4. References**

Chatelain, J. L. (1978), Etude fine de la sismicité en zone de collision continentale à l'aide d'un réseau de statios portables: la region Hindu-Kush-Pamir , *Thèse de 3 éme cycle*, Univ. Paul Sabatier, Toulouse.

Lomax A., Virieux J., Volant P. e Berge C., 2000: Probabilistic earthquake location in 3D and layered models: Introduction of a Metropolis-Gibbs method and comparison with linear locations - in Thurber C.H. e Rabinowitz N. (eds.): *Advances in seismic event location* - Kluwer, Amsterdam, 101-134.

Lomax A. and Curtis A., 2001: Fast, probabilistic earthquake location in 3D models using oct-tree importance sampling - *Geopys. Res. Abstr.*, 3, 955.

**5. Key publications/presentation**

*Will follow the completion of this deliverable.*

Deliverable D21

Title: Preliminary parametric catalogue of microearthquakes including source parameters (Irpinia test-site)

*end of phase I*

*prepared by:*
*Task 3 UR6 WP 3.2, Resp Claudio Satriano, Università di Napoli Federico II and AMRA scarl*

## 1. Description of the Deliverable

During the first 6 months of the project, we developed an automatic procedure for the inversion of the S-displacement spectra and the computation of the following source parameters: seismic moment, moment magnitude (Kanamori, 1977), corner frequency, Brune (1970) stress drop and source radius (Madariaga, 1976).

During the last 6 months, we thoroughly reviewed a selected data-set of 339 earthquakes recorded between 2005 and 2008, integrating the ISNet traces with recordings from the nearby INGV stations and manually picking the S arrival (which was previously estimated from the earthquake location). The total number of traces analyzed is 15297.

We computed the following additional parameters: radiated energy and apparent stress drop (Wyss, 1970).

The spectral model employed comprises a source term *S(f)* and a propagation term *P(f)*:

$$A(f) = S(f) \cdot P(f)$$

The source term is given by Brune (1970):

$$S(f) = \frac{\Omega_0}{1 + (f / f_c)^2}$$

where $\Omega_0$ is the spectral level for $f \rightarrow 0$ and $f_c$ is the corner frequency.

The propagation term takes into account for the attenuation, through the travel time $T$ and the quality factor $Q_S$.

$$P(f) = \exp\left(-\frac{\pi f T}{Q_S}\right)$$

We studied the $t^*=T/Q_S$ parameter as a function of the hypocentral distance. The results (figure 3) show that t* does not depend on distance (it is well represented by a Gaussian distribution centered on t*=0.027 sec), suggesting that $Q_S$ varies almost linearly with hypocentral distance.

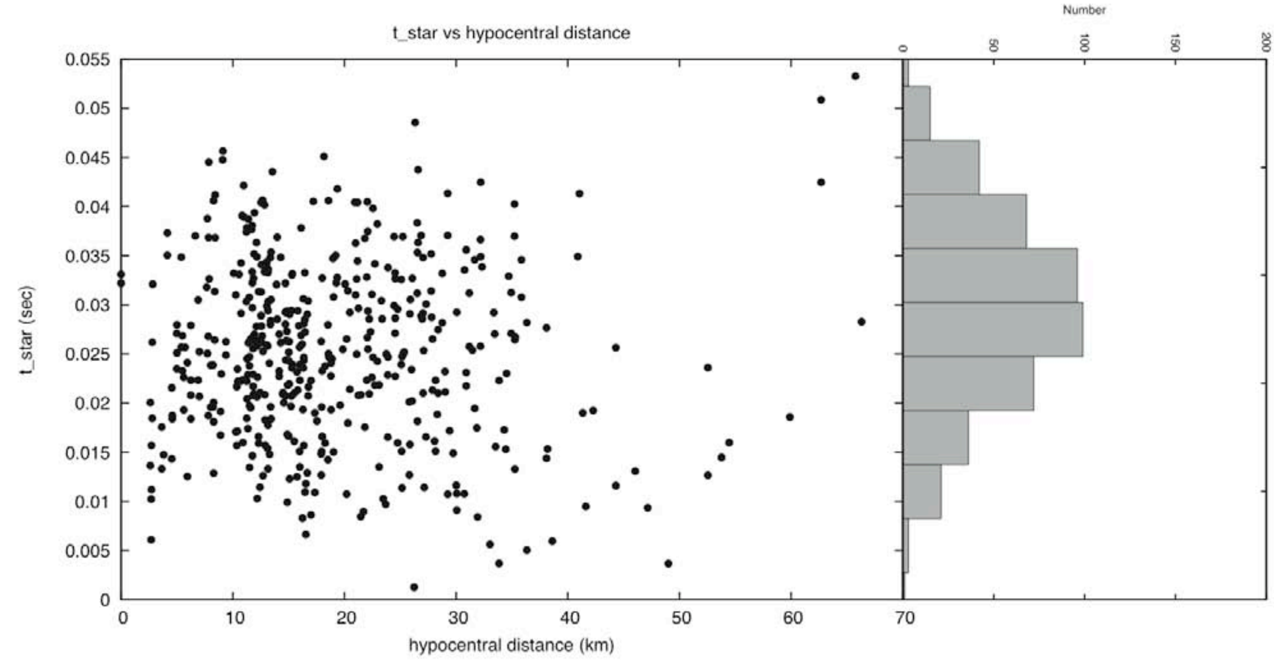



**Figure 3** The attenuation parameter t* as a function of the hypocentral distance, for earthquakes with *fc* >20 Hz. t* does not show a dependence on the distance, being well represented by a Gaussian distribution centered on t*=0.027 sec.

We therefore corrected the S wave spectra for a t* value of 0.027 sec and inverted the resulting spectral shape according to the Brune model.
The retrieved scaling plots for the source parameters are reported in figure 4.

The corner frequency shows week variability with the seismic moment Mo (figure 4a), violating the scaling law, especially for Mo < 1e12 Nm (Mw ~ 1.9).
The plot of Mo vs. the source radius (figure 4b) confirms the transition at Mo = 1e12 Nm, which is evident also in the graph of the Brune stress drop vs. Mo (figure 4c).
The radiated seismic energy (Er - computed from the integral of the spectrum) depends on Mo (figure 4d), but with a slope greater than expected from the relation $asd = \mu\, Er/Mo$ (where $\mu$ is the shear modulus - Wyss, 1970). This implies that the apparent stress drop (asd) varies with the seismic moment (figure 4e).
Finally, the apparent stress drop is correlated with the Brune stress drop (figure 4f), but is almost two orders of magnitude lower, in accordance with Abercrombie (1995).

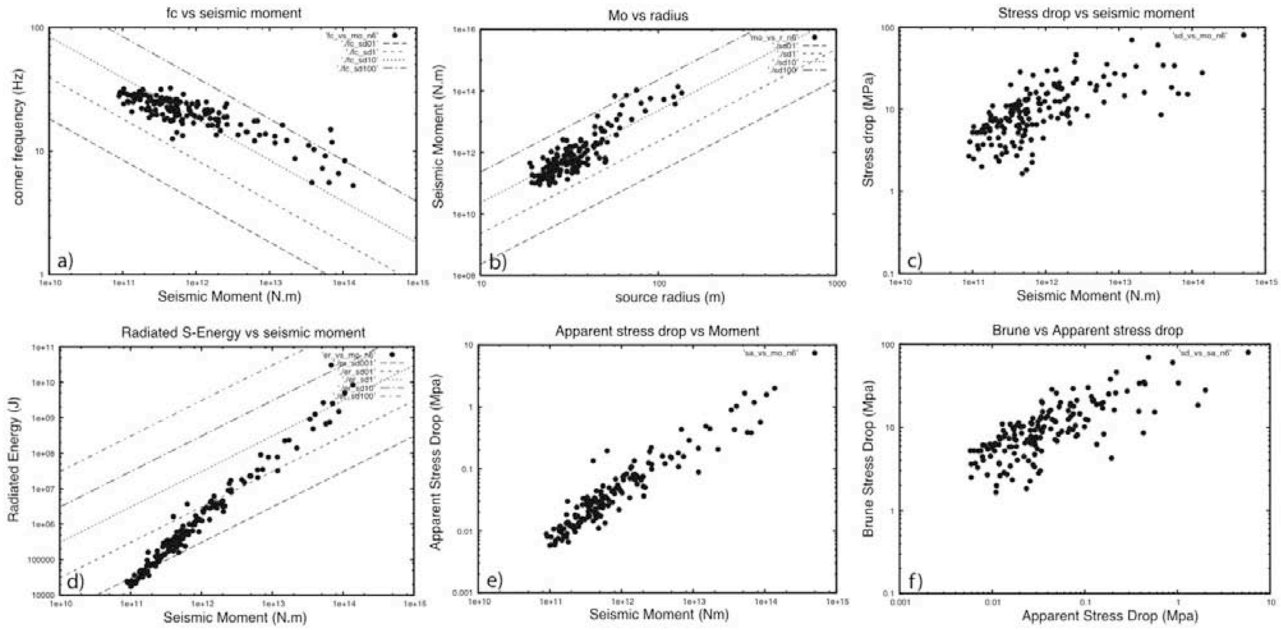



**Figure 4** Retrieved scaling for source parameters.

We deliver a preliminary version of a catalogue of source parameters for 161 selected microearthquakes with a number of readings greater than 6.

*1.2 File format*

The catalogue is delivered as a gzip compressed file: `D21-prel-sourcepar.dat.gz`.

The file is organized in 16 columns containing:

1. Moment magnitude (Mw)
2. Error on moment magnitude
3. Seismic moment (Nm)
4. Error on seismic moment (Nm)
5. Corner frequency (Hz)
6. Error on corner frequency (Hz)
7. Brune source radius (m)
8. Error on Brune source radius (m)
9. Brune stress drop (Mpa)
10. Error on Brune stress drop (Mpa)
11. Radiated energy (J)
12. Error on Radiated energy (J)
13. Apparent stress drop (Mpa)
14. Error on apparent stress drop (Mpa)
15. Number of readings used
16. Event source time in the form `yyyy.mm.dd.HH.MM`

## 2. Relevance for DPC and/or for the scientific community

This deliverable provides a complete set of source parameters for microearthquakes in the moment magnitude range 1.5-3 occurred in southern Apennines and recorded by the high density, high dynamics network ISNet owned by AMRA scarl. The availability of moment magnitude estimates allows to calibrate the local magnitude estimation which generally underestimates the earthquake magnitude in this specific magnitude range. The inferred scaling relationships for seismic energy, static and apparent stress release vs seismic moment shows that self-similarity can be extended down to about Mo 1e12 Nm in southern Apennines. The stress drop and attenuation parameters inferred from this study can be used to elaborate and update the ground motion prediction equations for southern Apennines to be used for seismic hazard analyses.

## 3. Changes with respect to the original plans and reasons for it

N/A

## 4. References


Abercrombie, R. E. Earthquake source scaling relationships from-1 to 5 ML using seismograms recorded at 2.5-km depth. *J. Geophys. Res.*, 1995.

Brune, J. N., Tectonic stress and spectra of seismic shear waves from earthquakes, *J. Geophys. Res.* 75, 4997-5009, 1970.

Kanamori, H., The energy release in great earthquakes, *J. Geophys. Res.*, 82, 2981-2987, 1977.

Madariaga, R., Dynamics of an expanding circular fault, *Bull. Seism. Soc. Am.*, 66, 639-666, 1976.

Wyss, M. Stress Estimates for South American Shallow and Deep Earthquakes. *J. Geophys. Res.* ol. 75 pp. 1529, 1970.


## 5. Key publications/presentation

*Will follow the completion of this deliverable.*