EGU2007 General Assembly
EGU2007-A-02319

New insights on seismicity pattern in the Lucanian Apennines (Southern Italy) and minimum 1D velocity model.

Cosmiana Maggi[1,2], Massimo Chiappini[1], Giovanni Battista Cimini[1], Rodolfo Console[1,2], Alberto Frepoli[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, 00143 Rome, Italy, www.ingv.it;* [2]*Centro di Geomorfolgia Integrata per l'Area del Mediterraneo, Via Francesco Baracca 175, 85100 Potenza, Italy, www.cgiam.org*

Introduction

The Southern Apennines belong to the complex geodynamic setting characterizing the Central Mediterranean region, which is dominated by the NNW-SSE convergence between the European and African plates. The tectonics of this area is accommodated by the collision between the Adriatic microplate and the Apenninic belt. The eastward migration of the extension-compression system derived by the subduction process of the Adriatic microplate is related to the opening of the Tyrrhenian Sea. Seismological data and recent geodetic studies reveal that the Apennines are undergoing a NE-trending extension, with seismic deformation rates higher in the southern portion.

Highly energetic events in the last four centuries are historically well documented. The strongest events are localized in the Apenninic chain, e.g. the 1694 earthquake that hit the Irpinia-Basilicata area with effects of the XI degree on the Mercalli-Cancani-Sieberg (MCS) scale and the 1857 Basilicata earthquake, located in the upper Val d'Agri and Vallo di Diano, with effects of the XI degree MCS. The last strongest earthquake hit the Irpinia-Basilicata area in 1980 with effects of the X degree MCS. On the contrary, the foredeep and foreland areas to the south of the Ofanto river do not show considerable historical earthquakes with the exception of the 1560 event that hit the towns of Barletta and Bisceglie with effects of the VIII degree MCS.

From the instrumental seismic catalogue 1981-2002 (Castello *et al.*, 2005) we observe that most of the background seismicity is concentrated along the Apenninic chain (Fig.1). Three main clusters of earthquakes are observable: 1) in the Potentino area, where concentrated the earthquakes of the two seismic sequences occurred in the years 1990 and 1991; 2) in the Irpinia region, and 3) in the Castelluccio area (1998 seismic sequence), close to the northwestern border of the Pollino range. The seismicity in the area between the Vallo di Diano and upper Val d'Agri is sparse as in the external areas of the Bradano foredeep and the Apulia foreland.

In this work, we have analyzed the seismicity of the last 6 years (2001-2006) recorded by the Italian National Seismic Network (RSNC) and by the temporary seismic array of the SAPTEX experiment (2001-2004) (Cimini *et al.*, 2006). The denser station coverage, with respect to that available in the past years, yields a significant improvement in the hypocentral locations. We used standard seismological methods to compute Vp/Vs ratio, one-dimensional velocity model, and station corrections for earthquake relocations. Focal mechanisms were computed using first motion polarities.

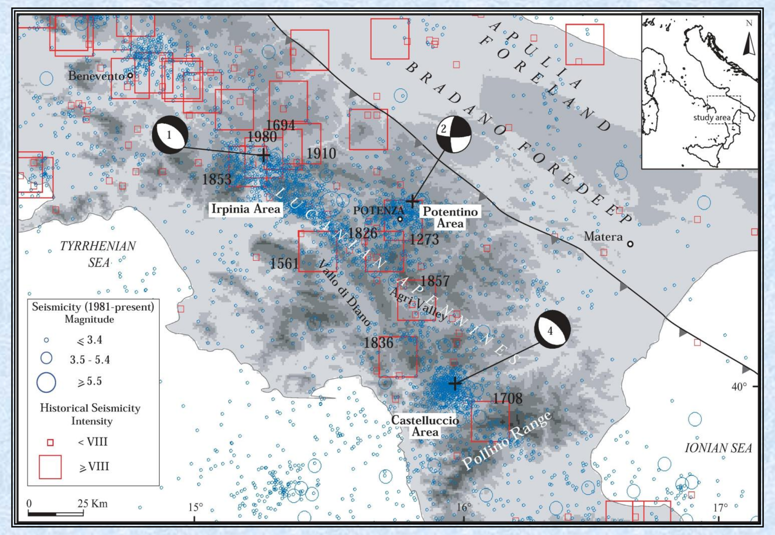

Fig.1: Seismicity of Southern Italy from 1981 to 2005 (CPTI Working Group, 1999; Castello *et al.*, 2005). Historical earthquakes are shown with the year of occurrence close to unfilled red squares with size proportional to the estimated magnitude. Focal mechanisms of the largest events in the Southern Apennines in the last 27 years are also shown (Irpinia 1980, Potentino area 1990 and 1991, Castelluccio area 1998).

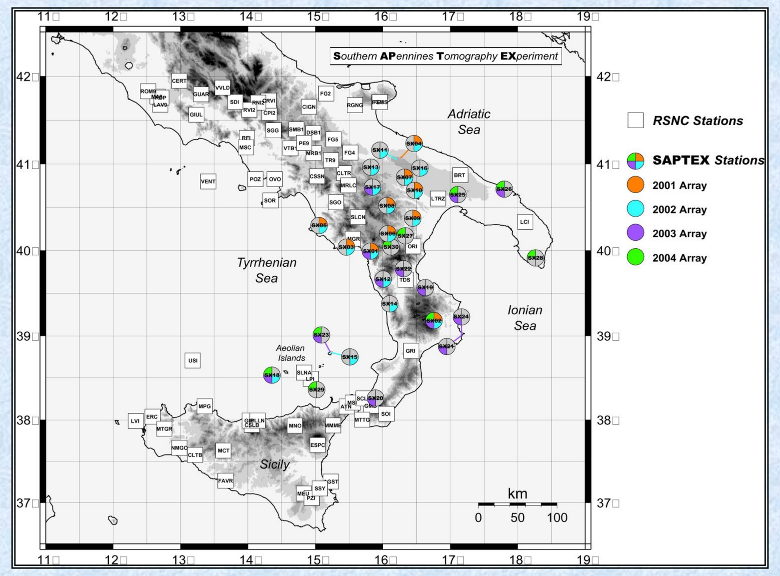

Fig.2: Italian National Seismic Network (RSNC) and SAPTEX temporary seismic stations. With white squares are shown the permanent stations of the RSNC and with circles are shown the temporary stations deployed for the SAPTEX tomographic experiment during 2001 (orange), 2002 (blue), 2003 (magenta), and 2004 (green) (Cimini *et al.*, 2006).

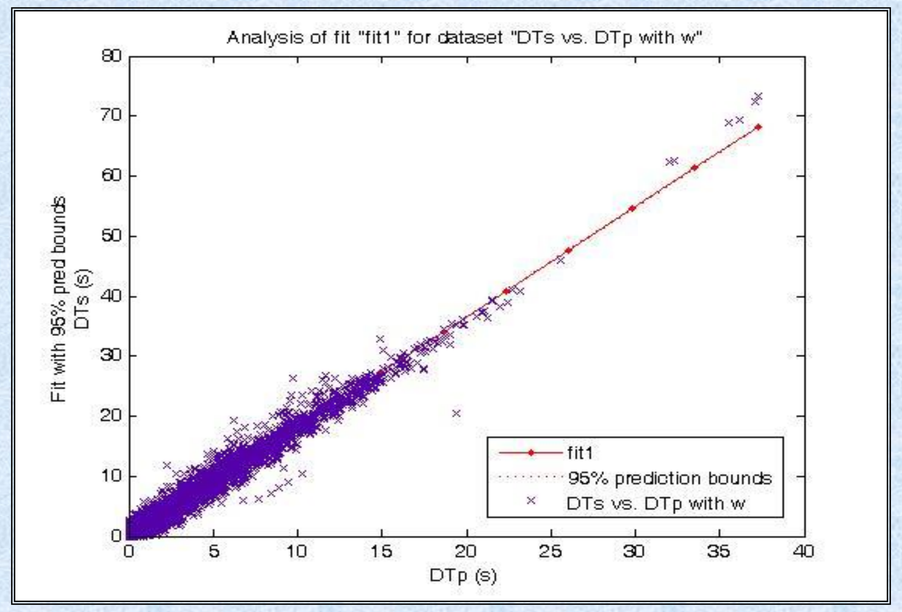

Fig.3: Linear fit of DTs versus DTp with 95% prediction bounds. The root mean squared error (RMSE) is 0.40, and the linear correlation coefficient (R) is 0.87. We plotted values with weights of 0, 1 or 2, considering the highest one among the four P and S weights (Pointoise and Monfret, 2004).

Data and analysis

We analyzed the seismicity of the Lucanian Apennines and Bradano foredeep in Southern Italy that occurred in the period June 2001 - December 2006. We re-picked P- and S-wave arrival times, for a total of 7570 P- and 4956 S-phases of 514 earthquakes with local magnitude (Ml) larger than 2.0. Events were recorded both by the Italian National Seismic Network (RSNC), operated by the Istituto Nazionale di Geofisica e Vulcanologia (INGV), and the SAPTEX temporary array deployed in the area from June 2001 to December 2004 for tomographic studies (Cimini *et al.*, 2006) (Fig.2). When available, we also used data recorded by the Eni-Agip seismic network located in the upper Agri Valley.

We computed an average Vp/Vs ratio using a modified Wadati method (Chatelain, 1978) obtaining a value of 1.83 (Fig.3)

To better constrain the hypocentral depths we performed an analysis to find the best P-wave one-dimensional (1D) velocity model for the crustal seismic structure of the study area, using the VELEST algorithm (Kissling *et al.*, 1995). We considered three starting models:

1) model obtained by Chiarabba *et al.* (2005) for the Italian region (Fig.4);

2) model by Chiarabba and Frepoli (1997) computed for the seismic structure of Southern Italy (Fig.5);

3) a P-wave velocity model named *Test* that we obtained from other Lucanian Apennines seismic studies (Frepoli *et al.*, 2005, Cassinis *et al.*, 2003) (Fig.6). As VELEST program doesn't invert for changes in layer thicknesses, we restratified the initial models (stratified models: *Model2, Model1 and Teststra*) finding a more appropriate model layering. After some tests, we derived the models in fig.7 (*Vel_8*, *Vel_9* and *Test8*). Since the models *Vel_8* with root mean square RMS=0.33, and *Test8*, with RMS=0.32, converged we used both to relocate our dataset using the HYPOELLIPSE code (Lahr, 1989).

We rejected the earthquakes with azimuthal gaps larger than 180° and root mean square larger than 1 s. Using these criteria, we relocated 304 events (56,9% with quality A and 23,1% B) for the model *Vel_8*, and 359 (67,7% with quality A and 16,4% B) for *Test8*, respectively (Table I). The results indicate that the model *Test8* is more appropriate than model *Vel_8*. The epicentral distribution of the local earthquakes relocated using the model *Test8* with HYPOELLIPSE is shown in Fig. 8 and Fig. 9. The pattern is consistent with results of previous studies (Chiarabba *et al.*, 1997, Frepoli *et al.*, 2005).

Finally we computed more than 160 fault plane solutions of earthquakes localized in the study area. From this data set we selected 69 fault plane solutions following the two output quality factors Q_f and Q_p of the FPFIT code (Reasenberg and Oppenheimer, 1985) ranging from A to C for decreasing quality. Q_f reflects the solution prediction misfit of the polarity data F_j, while Q_p reflects the solution uniqueness in terms of 90% confidence regions on strike, dip and rake. The average number of polarities for events used in this study is 15. The selected focal mechanisms for which A-A, A-B, B-A and B-B quality were obtained, are relatively well constrained (Fig.10a, Fig.10b). As shown from focal mechanisms of larger events, also from fault plane solutions of background seismicity we observe a widespread NE-SW extension in the Lucanian Apennines. Focal mechanisms calculated in this work are in large part normal and strike-slip solutions and their tensional axes (T-axes) have a generalized NE-SW orientation.

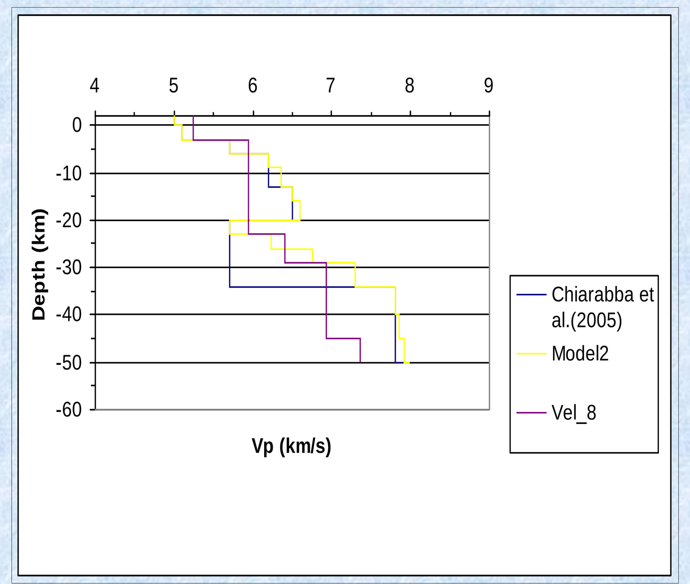

Fig.4: Starting P-wave velocity model for the Italian region computed by Chiarabba *et al.* (2005). We restratified this initial model introducing some layers with thickness of 3 or 4 km, up to 30 km depth, and of 5 km for greater depths. We named this model *Model2*. *Vel_8* is the final velocity model obtained with VELEST.

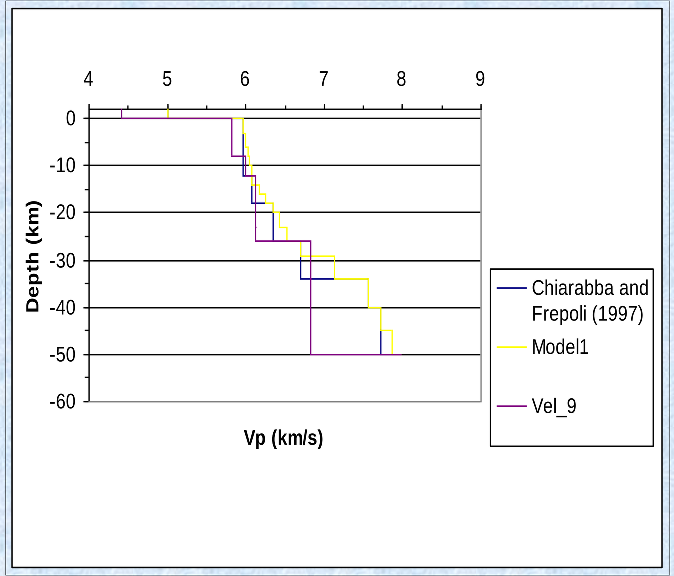

Fig.5: Starting P-wave velocity model for the Southern Italy by Chiarabba and Frepoli (1997). We restratified this starting model introducing some layers with thickness of 3 or 4 km, up to 30 km depth, and of 5 km for greater depth. We named this model *Model1*. *Vel_9* is the final velocity model obtained with VELEST.

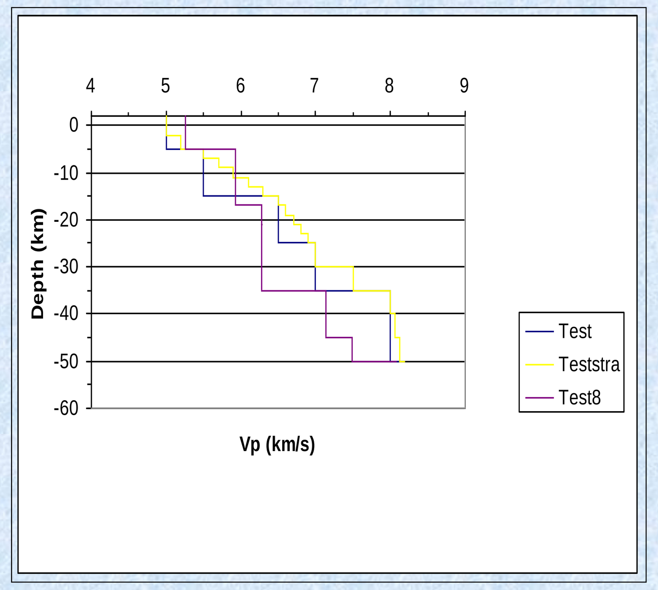

Fig.6: Starting P-wave velocity model *Test* for the Lucanian Apennines. We restratified this model introducing some layers with thickness of 3 or 4 km, up to 30 km depth, and of 5 km for greater depths. We named this model *Teststra*. *Test8* is the final velocity model obtained with VELEST.

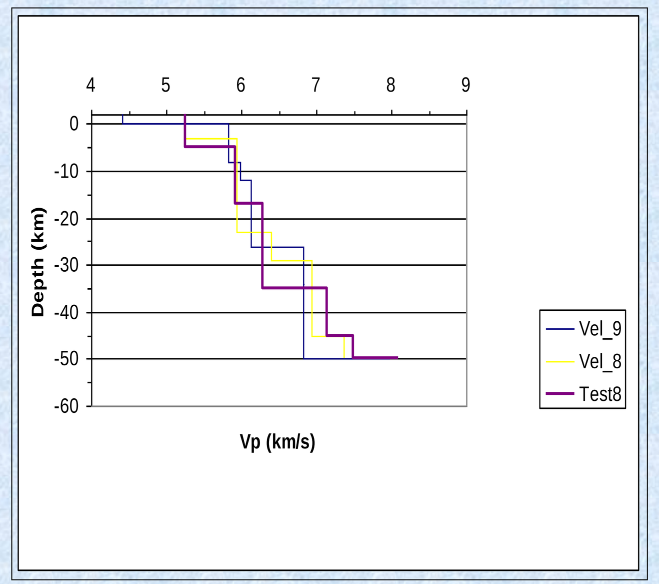

Fig.7: P-wave velocity final models obtained with VELEST. *Vel_8* is the model derived from *Model2*, *Vel_9* from *Model1* and *Test8* from *Teststra*.

Conclusive remarks

- The seismicity of Southern Italy in the area including the Lucanian Apennines and surrounding regions is carefully analyzed using a high-quality dataset of waveforms collected from a dense monitoring of the region in the last six years.
- We computed the Vp /Vs ratio using a modified Wadati method, obtaining a value of 1.83.
- An analysis for the one-dimensional (1D) velocity model that approximates the seismic structure of the study area is carried out obtaining the regional model called *Test8*. The Moho is put at 35 km depth consistently with others studies.
- We relocated 359 earthquakes with magnitude greater than 2.0. Relocations are well constrained and significantly improved with respect to those obtained by RSNC data only and by other previous studies concerning the period 2001-2002.
- Seismicity is concentrated beneath the Apenninic chain with an evident gap in the area included between Pollino and Sila range (Fig.9, section IL). Conversely, at the eastern margin of the chain, beneath the Bradano foredeep and the Apulian foreland, seismicity is deeper and sparse (Fig 9, sections AB, CD, EF).
- We selected 69 well-constrained fault plane solutions to investigate the stress regime in the region.
- The selected focal mechanisms show mostly normal and strike-slip solutions. The tensional axes (T-axes) display a generalized NE-SW orientation.
- Fault-plane solution will be used for stress inversion.

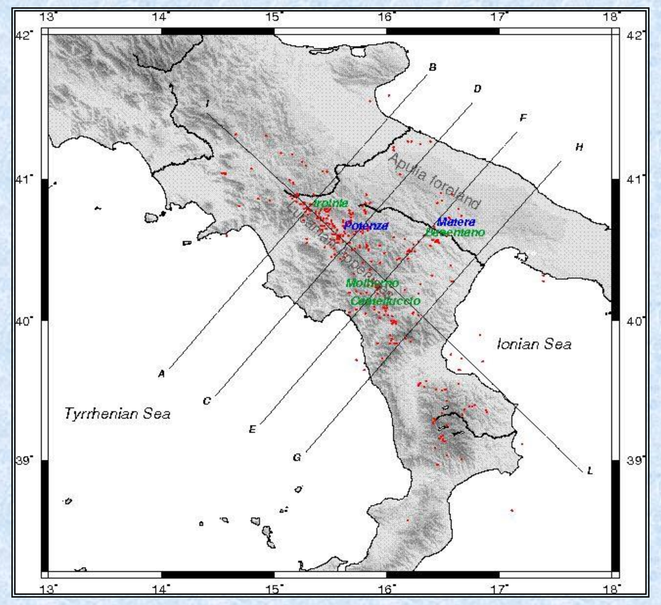

Fig.8: Horizontal distribution of 359 earthquakes located using the model *Test8*. The maximum earthquake distance from section AB, CD, EF, GH is 25 km and from IL 200 km, respectively.

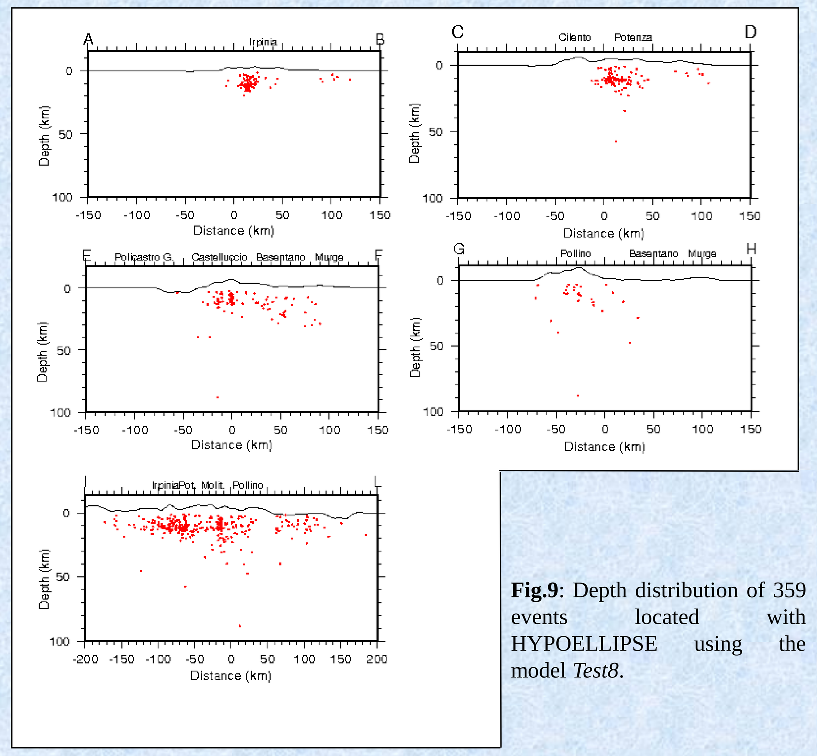

Fig.9: Depth distribution of 359 events located with HYPOELLIPSE using the model *Test8*.

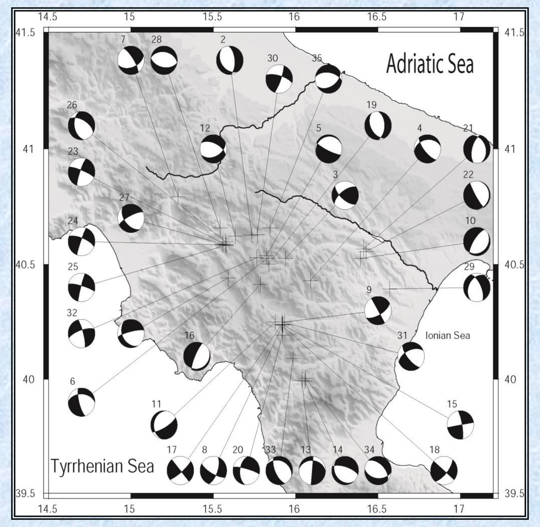

Fig.10a: Distribution of 34 well-constrained focal mechanisms of the 69 calculated.

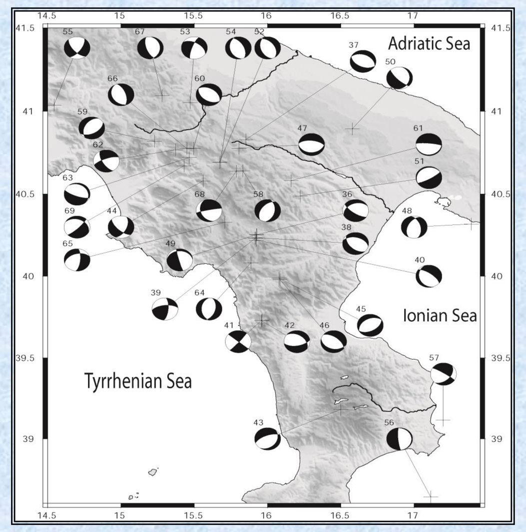

Fig.10b: Map of others 35 well-constrained focal mechanisms of the 69 calculated.

Quality	Larger of SEH and SEZ	Number of events of the model Test8	%number of events of the model Test8	Number of events model Vel_8	%number of events of the model Vel_8
A	≤ 1.34	243	67,7%	173	56,90%
B	≤ 2.67	59	16,40%	70	23,10%
C	≤ 5.35	25	7,00%	36	11,80%
D	> 5.35	32	8,90%	25	8,20%

Table I: Quality based on the value of the horizontal error SEH (68% confidence limit), and vertical error SEZ (68% confidence limit).

References

Cassinis, R., S. Scarascia and A. Lozej (2003): The deep crustal structure of Italy and surrounding areas from seismic refraction data. A new synthesis, *Boll. Soc. Geol. It.*,**122**, 365-376.
Castello, B., G. Selvaggi, C. Chiarabba and A. Amato (2005): *CSI Catalogo della sismicità italiana 1981-2002*, versione 1.0 (INGV-CNT, Roma), (on line: http://www.ingv.it/CSI/).
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.
Chiarabba, C. and A. Frepoli (1997): Minimum 1D velocity models in Central and Southern Italy: a contribution to better constrain hypocentral determinations, *Ann. Geofis.*, **XL** (4), 937-954.
Chiarabba, C.,L. Jovane and R. Di Stefano (2005): A new view of Italian seismicity using 20 years of instrumental recordings, *Tectonophysics*, **395**, 251-268.
Cimini, G. B., P. De Gori and A. Frepoli (2006): Passive seismology in Southern Italy: the SAPTEX array, *Ann. Geofis.*, **49** (2/3), 825-840.
CPT Working Group (1999): *Catalogo Parametrico dei Forti terremoti Italiani* (GNDT-ING-SGA-SSN). (Ed. Compositori, Bologna), pp.88.
Frepoli, A., F. R. Cinti, L. Amicucci, G. B. Cimini, P. De Gori and S. Pierdominici (2005): Pattern of seismicity in the Lucanian Apennines and foredeep (Southern Italy) from recording by SAPTEX temporary array, *Ann. Geofis.*, **48** (6), 1035-1054.
Kissling, E., W. L. Ellsworth, D. Eberhart-Phillips and U. Kradolfer (1994): Initial reference models in local earthquake tomography, *J. Geophys. Res.*, **99**, 19635-19646.
Lahr, J. C. (1989): HYPOELLIPSE/Version 2.0: a computer program for determining local earthquake hypocentral parameters, magnitude, and first motion pattern, *U. S. Geol. Surv. Open File Rep., 95*, 89-116.
Pointoise, B., T. Monfret: Shallow seismogenic zone detected from an offshore-onshore temporary seismic network in the Esmeraldas area (northern Ecuador), *Geochem. Geophys. Geosyst.*, **5** (2), 1-22.
Reasenberg, P. and Oppenheimer (1985): FPFIT, FPPLOT and FPPAGE: FORTRAN computer programs for calculating and displaying earthquake fault-plane solutions, *U.S. Geol. Surv. Open-File Rep*. 85-739.