

Task 1.4 Characterization of seismogenic sources in “potential gap areas”

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Participants:

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Recent studies have defined several regions in Italy with significant seismogenic potential, but the present available data are not sufficient to delineate in these areas the sources of possible large earthquakes that could occur in the close future. These regions are classified as “seismic gaps”: they could have experienced strong historical events but at present they show a quiescent stage of seismicity. Two areas having these characteristics are nearby Città di Castello (central Apennines) and the Pergola-Melandro basin (southern Apennines) both have been detected in detail within this project.

The goal of this task was to provide punctual and accurate data on those areas of Italy defined as “seismic gap”: areas characterized either by lack of historical and/or instrumental seismicity, or by scarcity of direct observations.

The first step concerned the adjustment of distinct methodologies for the investigation of “real or apparent” seismic gaps, and then have been evaluated new parameters on some of these areas. Each of the proposed approaches has given distinct and somehow independent data, whose analysis help to define the “hidden” seismogenic sources and to characterize them from a cinematic point of view.

We have analyzed:

- the spatial-temporal distribution of the instrumental seismicity;
- seismic sequences in bordering areas;
- focal mechanisms of earthquakes;
- active stress data along deep wells

We have performed:

- Structural and geomorphic analysis based on spot images, DEM, aerial photos interpretation, and field data;
- radiocarbon dating

We have analyzed and interpreted (in collaboration with ENI) along with the seismological and geological knowledge:

- seismic reflection lines crossing the selected areas.

We have used:

- DinSAR (differential SAR interferometry), to recognize and detect ground movements at medium-large scale.

The final product is:

1 - the identification and characterization of the seismogenic sources for the selected areas, in terms of geometric and kinematic parameters (strike, dip and rake, extent, slip rate value, age...), through the integration of different methods and attitudes

2 – Table containing geometric parameters

Pergola-Melandro area.

- This area is characterized, from a seismotectonic point of view, by an extensional stress field NE-SW oriented. Data from instrumental and historical seismicity, seismic sequence analysis and borehole breakout analysis are coherent. The results show a low-moderate seismicity distributed along this sector of southern Apennines, with few seismic sequences located close to the target area (Fig. 1, 2)
- Structural and geomorphic analysis based on spot images, DEM, aerial photos interpretation, and field data, evidence ~20 km long mainly normal fault, running on the western edge of the Pergola-Melandro basin (Fig. 1a, b).
- The extensional fault is composed by two main segments showing a left lateral *en-echelon* pattern. The average strike is between N320 and N350. The dip is between 70° and 75° toward east. In particular within a quarry excavated across a branch of the main fault trace, two deformation zones have been recognized.
- The first zone is characterized by a ~75° dipping, sharp tectonic contact between cataclastic dolomia and late quaternary deposits (Fig. 2). The whole sequence is in erosional contact in its uppermost part, with an undeformed organic silt deposit. A secondary zone of deformation is represented by a ~10 m wide graben in which are repeatedly faulted and tilted different colluvial silty-sandy deposits. The main fault is about 70° east dipping and is faced by a series of antithetic faults. The graben is a growing structure resulting from repeated faulting events (Fig. 3). There is a suggestion for cumulative movements at this zone related to at least four faulting events.
- We sampled the organic deposits exposed in the zones of deformation for radiocarbon dating. The ages of the two deformed paleosoils from both the fault zones at this site suggest that the events of deformation occurred in the last 10-12 ky. In the first zone the last undeformed deposit has been dated at 3300 y, B.P.
- The minimum net vertical displacement of the dated paleosoil across the graben is 3.6 m. Based on this measurement we estimate a minimum vertical long-term slip-rate of about 0.3 mm/yr at this site.
- The system ridge-slope-basin records significant differences between the northern and southern portion. The analysis of the landscape highlights that the Pergola-Melandro fault strongly influenced the recent morphological evolution of the basin. Complex rotational landslides are observed in the southern sector of the basin. In the central and northwestern sector, morphological elements of mass movements are present related to paleo landslides and Deep Seated Gravitational Slope Deformation in the carbonatic structures (see DSGSD in fig. 1).
- Val d'Agri/ Diano/ Pergola Melandro areas have been also investigated by means of Synthetic Aperture Radar (SAR) data. The main topic is the detection of surface movements by means of radar SAR Interferometry (InSAR). Well localized surface movements are detected, with rates of a few mm/year. They are partly due to DSGSD in the high-relief zones within the study area and to tectonic movements as well.
- The SAR dataset covers the time interval 1992-2000. InSAR coherence is not very good exception some areas. Differential interferograms point out very localized relative surface movements. No stable reference points are available to calibrate the interferograms.
- All the data collected along with this Project have been projected in terms of minimum horizontal Stress to reconstruct the σ_{Hmin} smoothed direction and its local variations (Fig. 6).

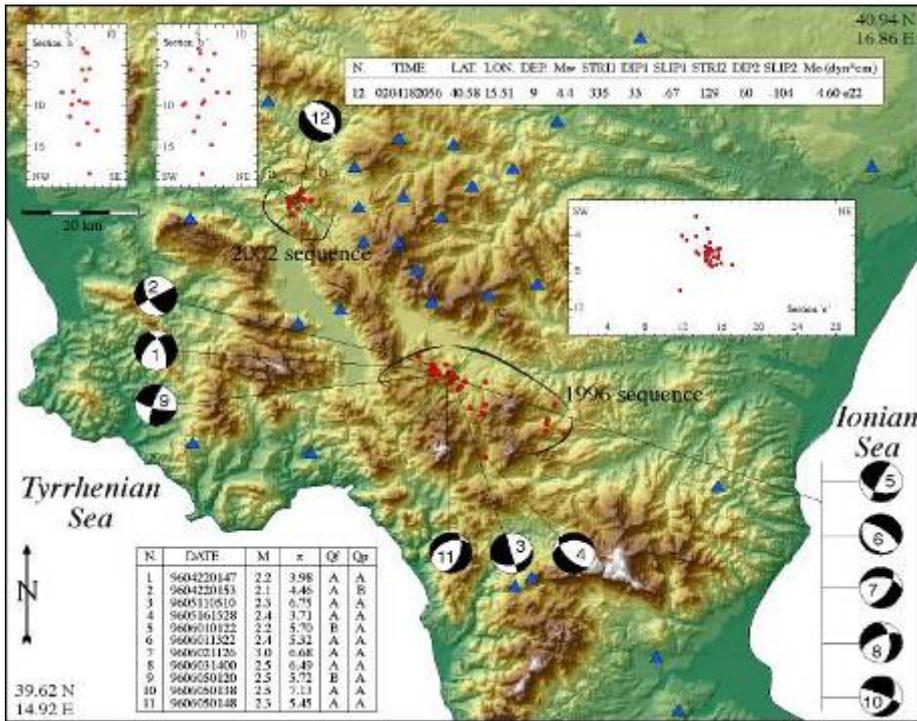


Fig. 1 - The 1996 and 2002 seismic sequence. Red dots show earthquake locations. Focal mechanisms from n.1 to n.11 belong to the 1996 sequence. Focal mechanism n.12 is the Quick CMT of the 2002 main shock. Blue triangles indicate seismic stations used to localize earthquakes. (Cucci et al., J.G.I., 2004)

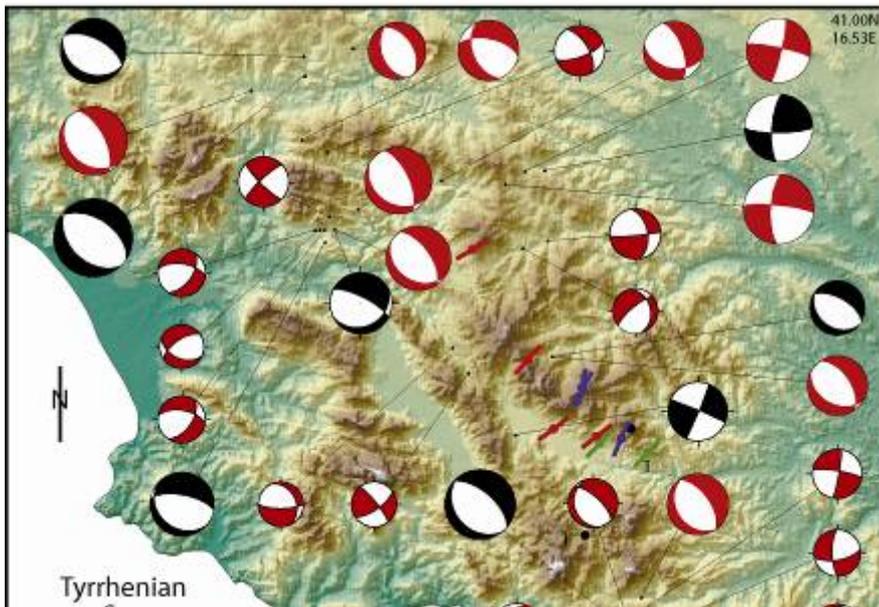


Fig. 2 - Focal plane solutions and breakout data. Black focal mechanisms are from the Harvard CMT Catalog, from Gasparini et al., 1985 and from Cocco et al., 1999. Red mechanisms are from this Project, first polarity solutions and CMT computations. Coloured bars indicate Shmin directions. (Cucci et al., J.G.I., 2004)

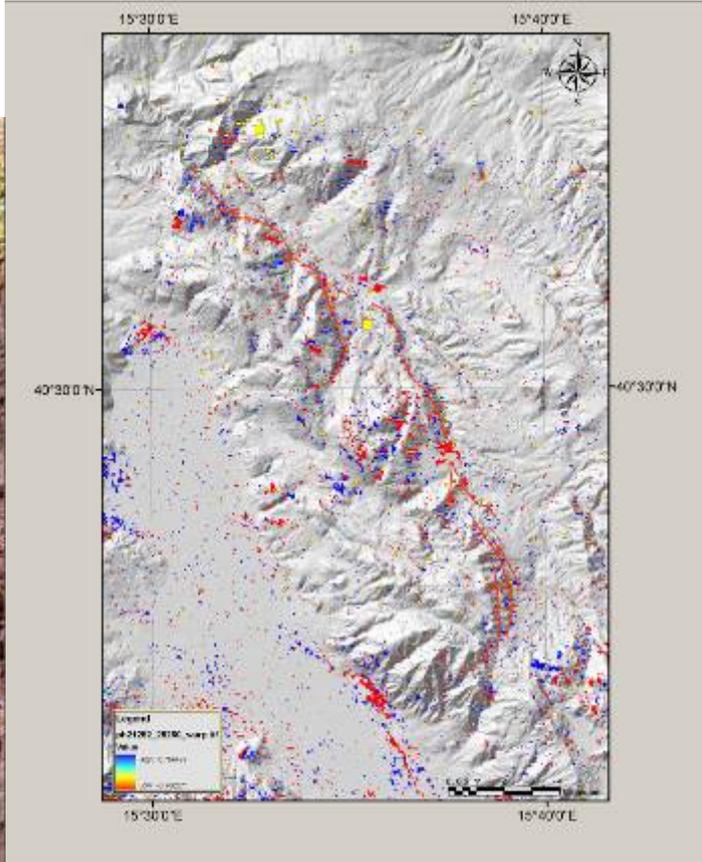
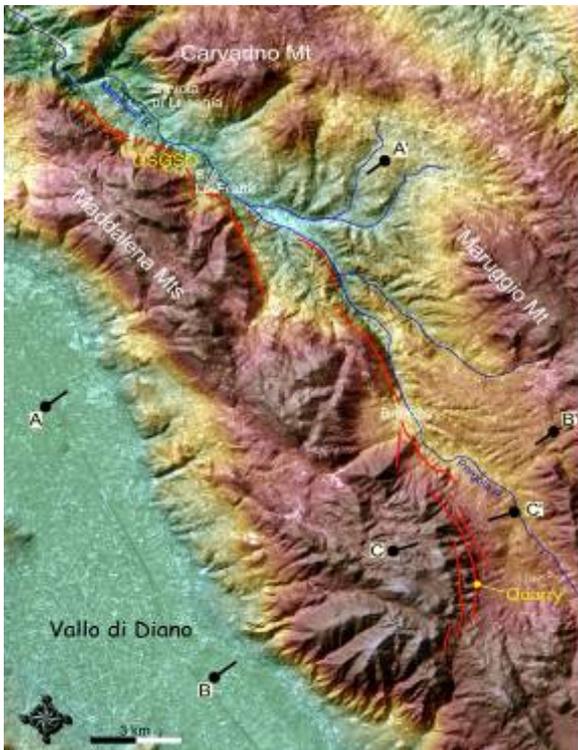


Figure 3 a, b - Trace of the Pergola-Melandro fault (red lines) and differential interferograms. Phase changes are in radiants. Coherence is mainly good in urban areas. Atmospheric contribution can be also present.



Figure 4, 5 – Outcrops at the quarry site. Several radiocarbon dating have been performed.

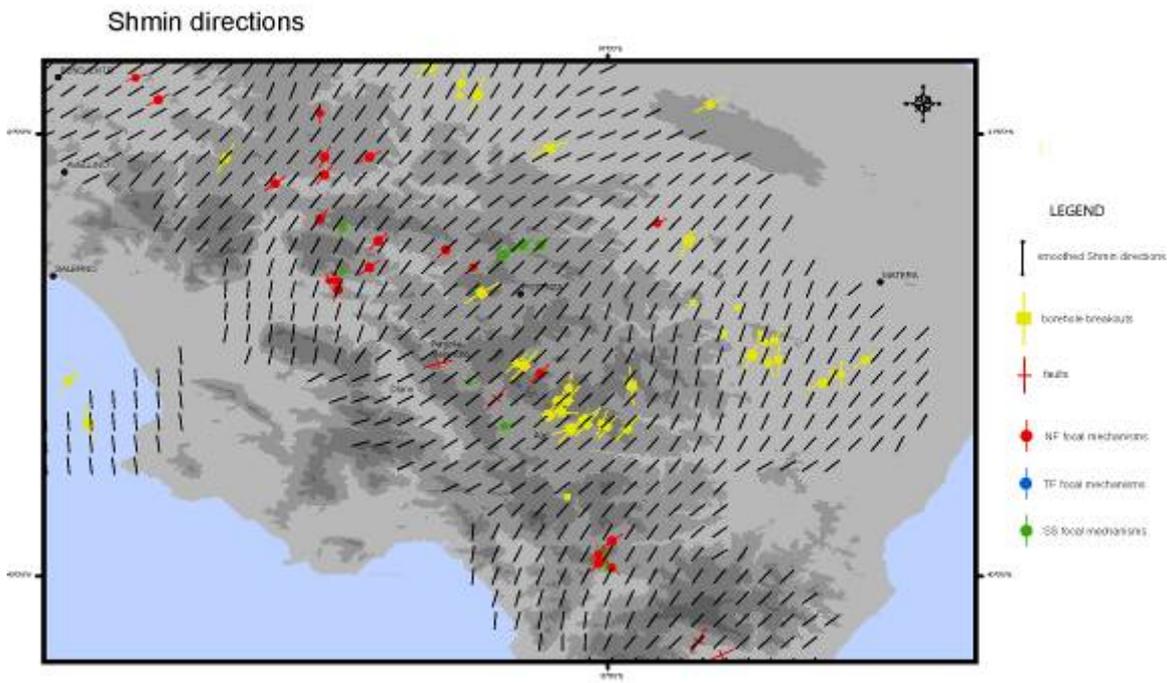


Figure 6 – Shmin smoothed direction for the Pergola-Melandro area.

TABLE: Pergola- Melandro fault parameters:

	LENGTH	WIDTH	STRIKE	DIP	RAKE	SLIP RATE
PM fault	20 km	10-13 km	N 320-350	70-75NE	270	0.3 mm/yr

Città di Castello-Sansepolcro area

- In collaboration with Perugia University, a few reflection seismic lines, crossing the sector between the Tiber valley and the Apenninic belt, have been interpreted to reconstruct the geometry and kinematics of the main structures in the area (in combination also with the GNDT Project by M. Cocco).
- Field surveys mainly based on structural, idrological and geological analysis have been performed to characterize the geometric and the tectonic setting of this basin (Figure 7).
- At least two main structures are defined (the Alto Tiberina fault (ATF) and an antithetic one (AATF). Although the crustal seismicity is mostly concentrated in the area struck by the 1997 Umbria-Marche seismic sequence (Figure 8 a, b), also here, some seismic sequences are located in the northern sector of CC-SS basin showing the presence of two NW-SE seismogenic structures with opposite dip.
- Available SAR data cover the time period 1992-2000. 14 interferograms have been computed. For both areas a 20-m pixel size Digital Elevation Model (DEM) has been used to subtract the topographic contribution. The selected interferometric pairs have very short spatial baselines to reduce the topographic contribution almost at all. Moreover the use of the 20-m pixel size DEM completely erases it. For this reason, the residual differential fringes indicate surface displacements, except for the possible presence of atmospheric fringes (Figure 9 a, b).
- Also for this area and for the surrounding regions, we have determined an active stress map in which the smoothed stress directions are reported considering all the data also from this Project (Figure 10).
- For the ATF fault: The average strike is between N320 and N330. The average dip is 30° toward east. The length is 18 km, the width is 6 km. Its kinematics is prevalent normal fault. Top of the structure: 3 km depth; bottom: 6 km depth.
- For the AATF fault: average strike between N130 and N160. Average dip is 40° toward west. The length is 20 km, the width is 5 km. Kinematics: prevalent normal fault. Top of the structure: 1 km depth, bottom: 4-5 km depth.
- AATF is cut by ATF at a depth of 3-5 km beneath the CC-SS basin. ATF and AATF faults are composed by at least two other parallel segments.

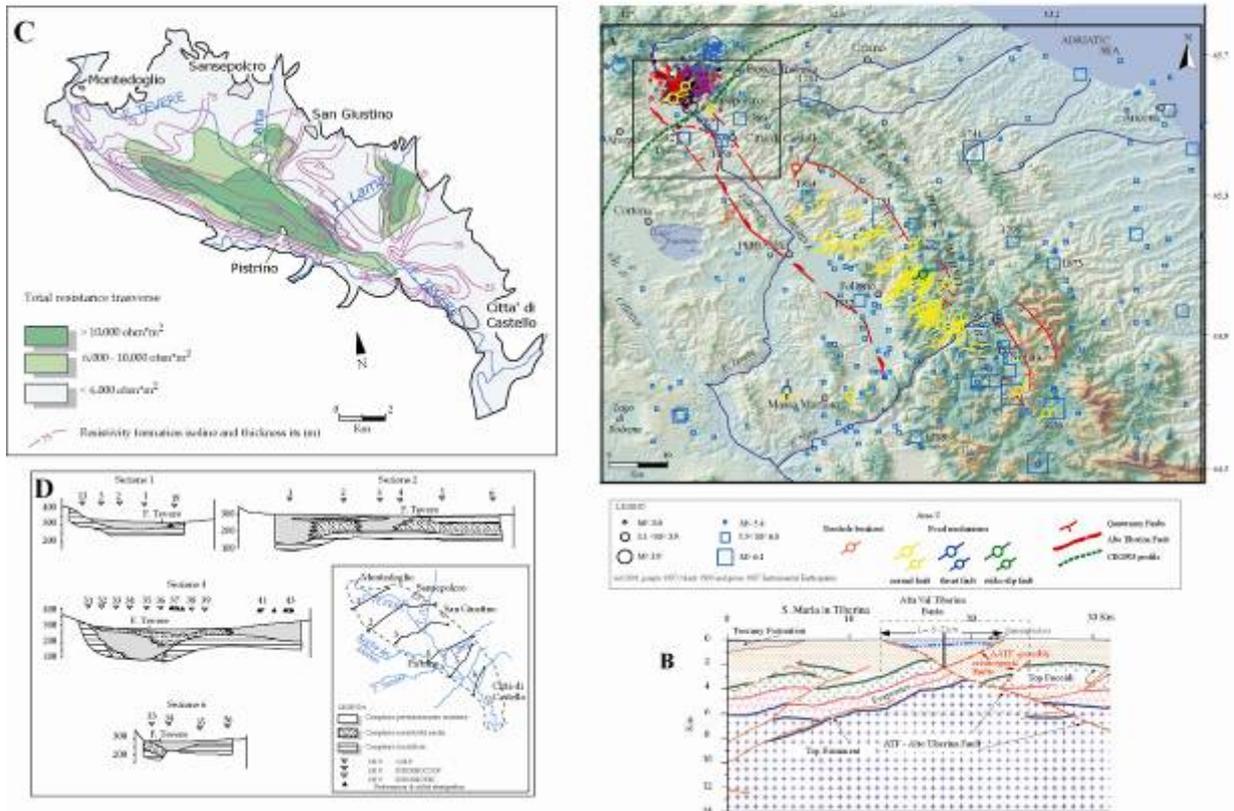


Figure 7 – Geometric setting of the basin from geological data. The CROP 03 line is also shown, with the two main seismogenic structures (ATF and AATF faults).

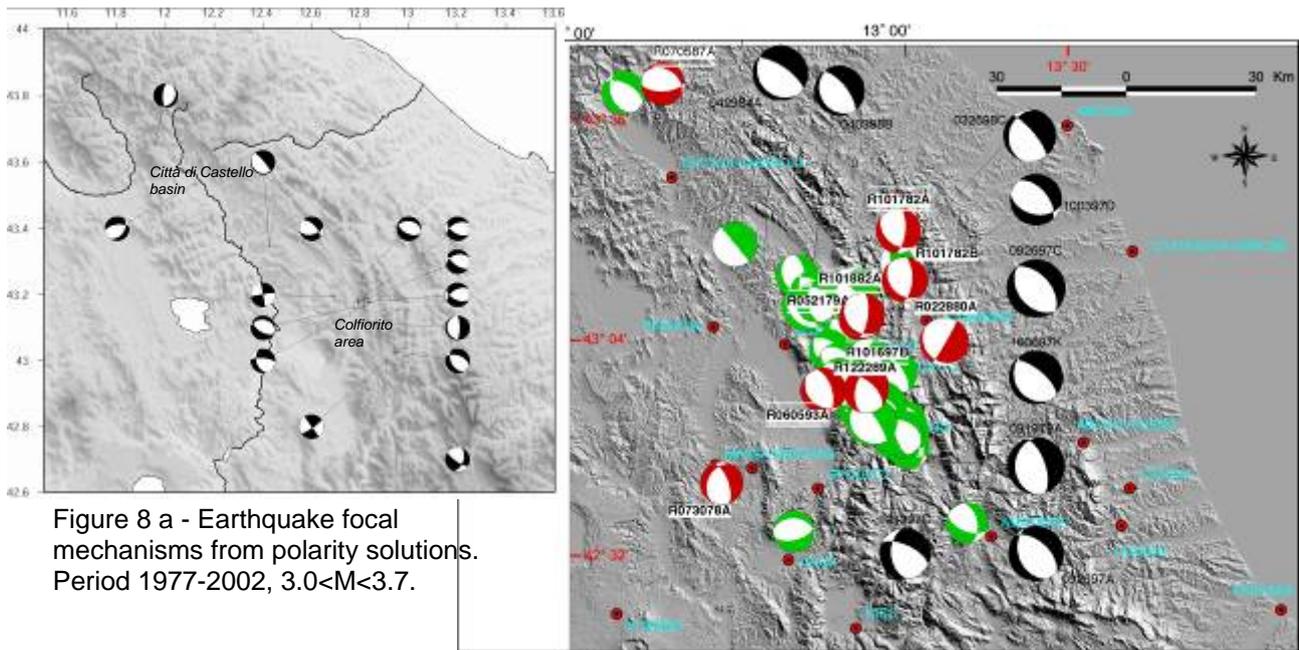


Figure 8 a - Earthquake focal mechanisms from polarity solutions. Period 1977-2002, $3.0 < M < 3.7$.

Figure 8 b - Source parameters determination for events with moderate magnitude occurred around the studied gap area of Città di Castello between the 1977 and the present using CMT method. Standard CMT (Harvard) in black, RCMTs in green and solutions computed in this Project are in red.

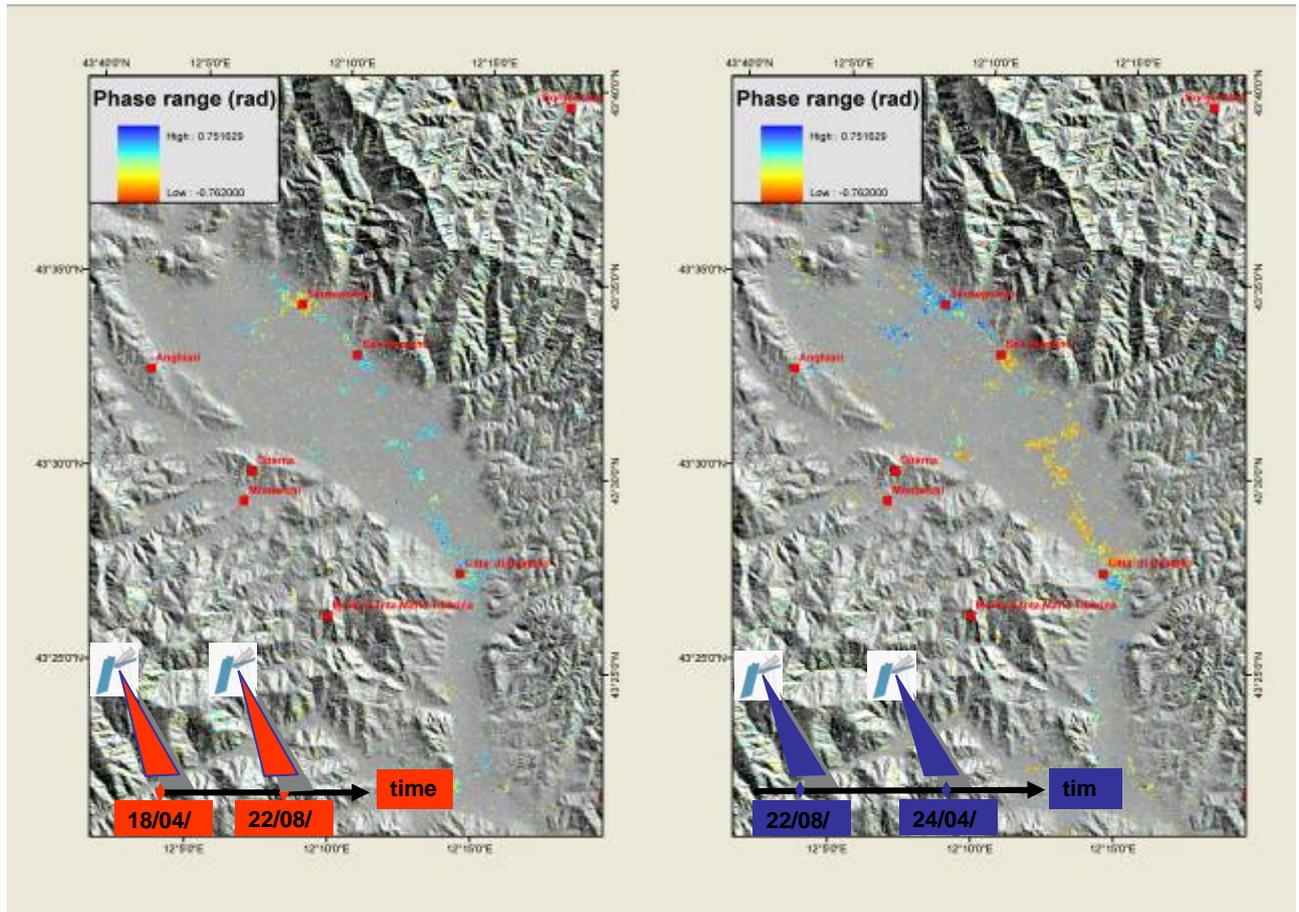


Figure 9 a, b – 3-year (1992-1995) and 1 –year (1995-1996) interferograms.

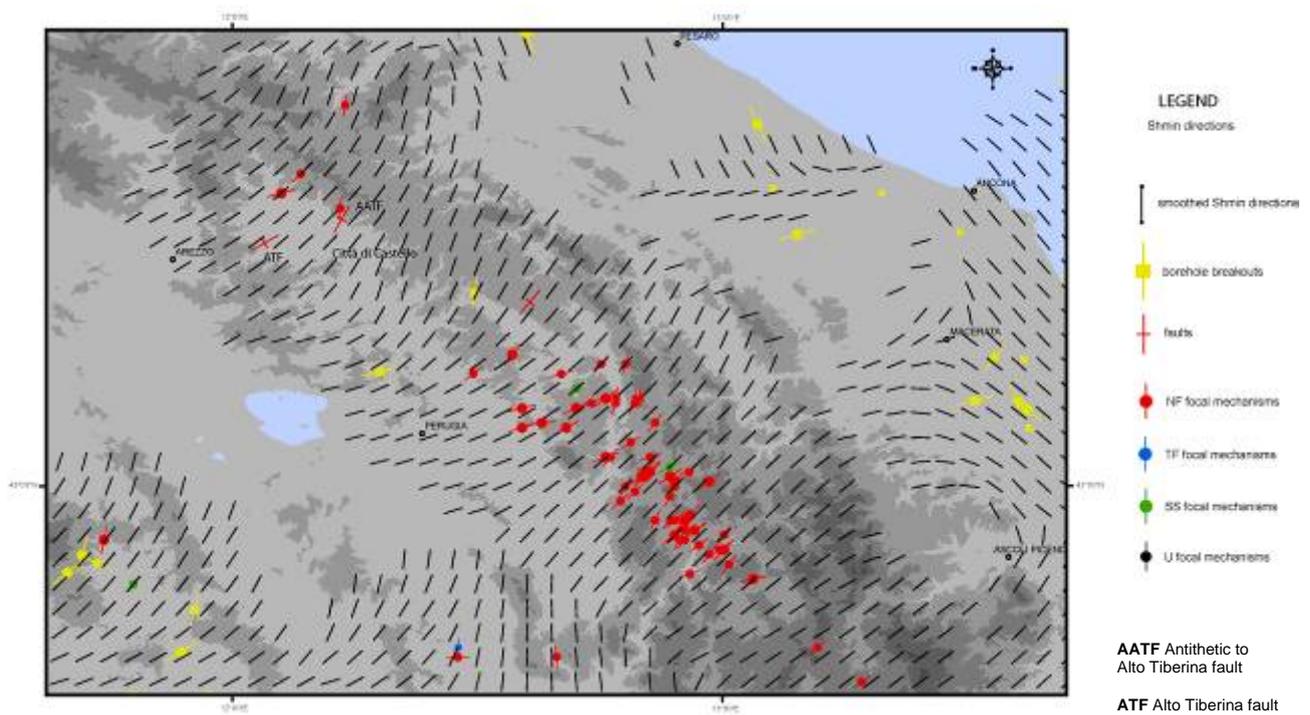


Figure 10 - Shmin smoothed direction for the Città di Castello – San Sepolcro area.

TABLE: ATF and AATF fault parameters:

	LENGTH	WIDTH	STRIKE	DIP	RAKE	SLIP RATE
ATF fault	18 km	6 km	N320-330	30NE	270	
AATF fault	20km	5km	N130-160	40SW	270	

Conclusions: The main goal of this Task has been achieved through the definition of the seismogenic structures in regions previously described as seismic gap areas. All the methods used (geological, geophysical, InSar) have contributed, at different level of completeness, in the characterization of the structures. The multidisciplinary approach proposed at the beginning of the project has revealed effective to constrain and study hypothesised seismogenic structures.

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