A multidisciplinary approach to the seismotectonics of the Lunigiana and Garfagnana extensional basins (Northern Tuscany, Italy)

F. BROZZETTI [(1)], P. BONCIO [(1)], D. DI NACCIO [(1)], G. LAVECCHIA [(1)], D.P. TINARI [(1)], L. TORELLI[(2)], M. BERNINI[(2)], E. EVA [(3)] AND S. SOLARINO[(3)].

[(1)] GeoSisLab – Dipartimento di Scienze della Terra, Università di Chieti-Pescara.

[(2)] Dipartimento di Scienze della Terra, Università degli Studi di Parma.

[(3)] Istituto Nazionale di Geofisica e Vulcanologia, CNT, c/o DipTeRis - Università degli Studi di Genova.

New geological and morpho-structural surveys are integrated with seismological and seismic reflection data in order to define the active and potentially seismogenic sources of the Lunigiana and Garfagnana extensional basins (Tuscany, Northern Italy). The seismogenic role of the E-W-striking transfer fault between the Lunigiana and Garfagnana basins, located at the northern termination of the Apuane metamorphic core, and its possible association with a number of historical earthquakes are also discussed.

The Lunigiana and Garfagnana basins are two NW-SE-striking asymmetric grabens, originated in the hanging wall of regional low-angle detachment faults, sloping gradually beneath the Apennine chain. These faults are referable to the northern termination of the Etrurian Fault System (EFS, BONCIO *et alii*, 2000), a Plio-Pleistocene en échelon fault-array made of east-dipping low-angle normal faults. South of the Garfagnana, the EFS includes the Mugello, the Casentino and, more to the south, the Tiber grabens.

The Lunigiana and Garfagnana grabens are bounded inward by an east-dipping normal fault set and outward by a west-dipping fault set. Each set consists of several normal fault alignments rooting on the detachment at increasing depths, from 1 to 2.5 sec TWT, from

W to E. In the Lunigiana, the depth geometry of the detachment and of the main high-angle normal faults has been precisely defined through a detailed interpretation of three seismic lines (see also CAMURRI *et alii*, 2001 and ARGNANI *et alii*, 2003). The detachment fault crops out along the eastern border of the Mt. Picchiara-Mt. Cornoviglio horst and deepens under the chain down to the depths of 4.5-5 sec TWT (~12-15 km).

The field survey of the faults showing evidence of Quaternary activity has been carried out with particular attention, in order to detect their dip-angle and segmentation pattern. The outcrop expression of the two conjugate sets is similar, but the east-dipping faults show, on average, lower dip-angles (i) (30°<i<60°, increasing from W to E) and higher cumulative displacement (D) values (D>4 km) than the west-dipping ones (50°<i<70°, D~2.5 km). The kinematic analysis on major faults shows that the more recent movements are normal or slightly oblique and are coherent with a tensional stress field characterised by a sub-horizontal NE-SW-trending sigma 3 axis.

In the Lunigiana, the east-dipping Mulazzo and Olivola faults (the outermost of the east-dipping set) and the Groppodalosio and Compione faults (the outermost of the west-dipping set) show the strongest geomorphic signature and are the most likely active faults. This is also confirmed by the geomorphic analysis carried out integrating aerial photograph interpretation and medium resolution DTM analysis.

An E-W tectonic lineament, detectable in aerial photographs and well evident in seismic line, is present between the Lunigiana and Garfagnana grabens, from Tendola to Equi Terme and Gramolazzo. This alignment, here named “North Apuane Fault Zone”, may be interpreted as an active right-lateral transfer fault zone between the two grabens.

In the Garfagnana, the NW-SE striking Casciana-Sillicano e Bolognana-Gioviano east-dipping faults show morpho-structural evidence of Late Quaternary faulting and can be interpreted as active and potentially seismogenic structures rooting at depth of 3-4 km on the basal detachment. Along the eastern side, the major antithetical Quaternary faults crop out along the M. Prato-Colle Uccelliera-M. Mosca ridge.

Our seismotectonic analysis integrates the geological and morpho-structural data with the available instrumental and historical earthquake catalogues. The instrumental dataset consists of the earthquakes recorded by the Lunigiana-Garfagnana local Seismic Network from 1999 to 2006. About 500 earthquakes (0.4≤Ml≤4.2) have been accurately located by using a probabilistic non-linear program which computes the maximum hypocentral probability through a 3D research algorithm (LOMAX *et alii*, 2000). The obtained errors for the hypocentral locations and the related residuals are small if compared with those coming from "standard" procedures. In the Lunigiana, the seismicity concentrates east of the M. Picchiara - M. Cornoviglio horst (Pontremoli and Aulla grabens). The Garfagnana area shows very low background seismicity, with few epicentres concentrated east of the Apuane Alps. On SW-NE oriented vertical sections, the hypocentres mainly locate within the upper 15-20 km and affect progressively thicker crustal volumes moving from W to E. In correspondence of the Pontremoli and Aulla grabens, earthquakes occur at depths shallower than 5 km, whereas under the Apennine ridge they reach 20 km depths. The depth-distribution is also accompanied by a concentration of the hypocentres within a narrow volume dipping at ~30° eastward. This east-dipping geometry of the seismicity is particularly evident across the Aulla basin. An integrated and revised database of earthquake focal mechanisms from 1939 to 2006 indicates the existence of a 30 km-wide belt, extending from the western border of the Lunigiana-Garfagnana grabens to the Apennine chain, characterized by prevailing extensional mechanisms (average N40°-E stretching direction), in agreement with geological data. On the whole, instrumental seismicity is consistent with the present activity of the basal detachment and of the associated high-angle structures, at least as the Lunigiana area concerns. The integrated analysis of geological and seismological data, including historical earthquakes (e.g.

February 14, 1834, I=VIII-IX M~5.6; May 7, 1481, I=VIII-IX M~5.8 earthquakes), suggests that the more active and potentially seismogenic structures are the Mulazzo and Olivola-Soliera faults (NE-dipping) and the Groppodalosio and Compione-Comano faults (SW-dipping). Other SW-dipping faults showing evidence of Late Quaternary activity, are not considered seismogenic due to their shallow decollement depths (~2 km).

Another subject of considerable importance is the seismogenic role played by the North Apuane Fault Zone (NAFZ). Our interpretation associates a primary seismogenic role to the NAFZ, as suggested by the October 1995 earthquake (M = 4.9) and its focal mechanism. We associate to the NAFZ also the April 11, 1837 earthquake (I=IX-X, M~5.7) plus a number of small-magnitude earthquakes (4.5≤M≤5.2) occurred in 1767, 1902, 1928 and 1962. The September 7, 1920 earthquake, which is the largest event of the Lunigiana-Garfagnana area (I=IX-X, M~6.5), could be associated to a complex rupture involving the entire Casciana-Sillicana fault plus the eastern portion of the NAFZ.

REFERENCES

ARGNANI A., G. BARBACINI, BERNINI M, CAMURRI F., GHIELMI M., PAPANI G., RIZZINI F., ROGLEDI S. E TORELLI L. (2003). *Gravity tectonics driven by quaternary uplift in the Northern apennines: insight from the La Spezia-Reggio Emilia geo-transect.* Quaternay International **101-102**, 13-26.

BONCIO P., BROZZETTI F. E LAVECCHIA G. (2000) - *Architecture and seismotectonics of a regional Low-Angle Normal Fault zone in Central Italy.* Tectonics, **19**, 1038-1055.

CAMURRI F., ARGNANI A., BERNINI M., PAPANI G., ROGLEDI S. E TORELLI L. (2001) – *The basement of the NW Apennines: Interpretation of reflection seismics and geodynamic implications.* GEOITALIA 2001, 3° Forum Italiano di Scienze della Terra, Chieti 5-8 Settembre **2001**, Fist Riassunti, 50-51.

LOMAX A., VIRIEUX J. E THIERRY-BERGE C.(2000). *Probabilistic earthquake location in 3D and layered models*, in Advances in Seismic Event Location, pp. 101–134, eds Thurber, C.H. & Rabinowitz, N., Kluwer Academic, Amsterdam.