Summary of the Paolo Marco De Martini PhD Thesis

Combined geodetic and geologic analysis of crustal deformation at different time scales:

A contribution to the identification and characterization of seismogenic structures in the Apennines (Italy)

The methodologies used for the identification of the active faults and particularly for the estimation of their seismogenic potential are often characterized by uncertainties and different interpretations. Recent studies showed persistent difficulties in identifying active structures when the recent deformation superimposes on older tectonic phases. These considerations are even more evident along the Apennines mountain chain, where each active fault is characterized by slip rate = 1.0 mm/yr and by average recurrence time between 1 and 5 kyr. These observations appear to be confirmed by the "hidden" or "blind" behavior shown by many active structures in Italy like those of Messina, Friuli, Irpinia, Val Comino, Gubbio, Colfiorito and Molise.

The works presented in this thesis discuss the problems related to the active faults of the Apennines. These problems are listed in the following:

1. The active deformation of the Apennines, which includes the tectonic movements along faults, is often obliterated by human activity (agriculture), high erosion rates due to climatic effects that often may be the source of wrong interpretations, and interference from older geologic structures.
2. The tectonic movements that dominate the Apennines tectonic style ask for the analysis of conventional leveling profiles (at least for the past century of observation) that are more precise with respect to measurements done by space geodesy, when the measurements refer to the vertical component of movement.
3. The study of active faults and its implication for the estimate of the seismic hazard ask for a multidisciplinary geologic, geodetic and seismologic approach for the characterization of the seismogenic sources and for the seismic hazard and risk calculation. In this thesis, we examine the abovementioned problems and provide some answers based on many examples of studies of seismogenic zones in the Apennines. Several our articles on international journals (level A) support our observations, measurements and analyses.

This thesis is made by seven (7) chapters:

Chapter 1 presents the seismotectonic characteristics of the Apennines and their recent tectonic evolution. The main tectonic structures of the Apennines, subdivided in distinct zones (North-, Central-and South-Apennines), are defined by: a) historical and instrumental seismicity, b) present stress field, c) known active faults. We use also the characteristics of the seismic hazard of the Italian peninsula for the analysis of the active zones.

Chapter 2 summarizes methodologies and principles of the active tectonics, seismotectonics and geodesy applied to active zones. The theoretical aspects of the active deformation (seismic) are presented with respect to the seismic cycle. We also present a short introduction to active tectonics and earthquake geology, as developed in the past decades. A case study of a region characterized by high seimic potential (Kahrizak Fault) in Iran, close to Teheran (De Martini et al., 1998) is shown. On the contrary, the example of a paleoseismological study of a stable zone in Australia highlights limitations of the applied methodologies and complexity of the active zones (Crone et al., 2003). The study of the Atalanti Fault (Central Greece, Pantosti et al., 2004) is shown in order to emphasize similarities with the normal faults acting in the Apennines.

In a second part, this thesis also describes the geodetic leveling technique and the history of the Italian geodetic leveling network. We highlight also the leveling errors and precision in order to describe the quality of the measurements performed in the past century in the Apennines (D'Anastasio et al., 2006). The analysis of the results is associated to modeling of the preseismic, coseismic and postseismic deformations.

A third part explains the need for the use of old geodetic data combined with active tectonic studies and the analysis of the seismicity pattern for a better understanding of: i – the deformational processes (preseismic, coseismic, postseismic and interseismic), and ii – the regional scale deformation. A comparison between short- and long- term deformations allows us to constrain the geometrical characteristics and the behavior of the Apennines active faults.

Chapter 3 shows evidence for preseismic and aseismic movements along active normal faults. Repeated geodetic measurements across the seismic zone of the Umbria-Marche Apennines, locus of the 1997-98 seismic sequence, demonstrate the existence of preseismic movements along a blind seismogenic fault (De Martini & Valensise, 1999). The geodetic evidence for aseismic slip along the Amatrice normal fault, lacking recent seismicity and creeping at the surface, highlights the problem of the silent faults.

Chapter 4 describes the evidence for coseismic movements along normal faults through geodetic and geologic data. Leveling measurements, performed soon after the Umbria-Marche 1997-98 seismic sequence, allow a better estimate of the seismic source parameters and of the distribution of the coseismic slip (De Martini et al, 2003). Change in the deformation rates of the blind normal faults activated during the seismic sequence and the conjunct analysis of the InSAR data through surface deformation modeling, allow us to better localize a minor fault splay (Stramondo and De Martini, 2004). The geologic evidence for active and seismogenic faults is derived from different paleoseismological works we took place, and demonstrates the relationship between short- and long- term deformation in the Apennines (Pantosti et al., 1999).

Chapter 5 discusses the geodetic leveling measurements performed in the intermontane Fucino basin, locus of the large 1915 earthquake. The repeated surveys and the identification of deformation (together with a modeling approach) show the presence of postseismic deformation probably related to relaxation effects of tectonic crustal origin (Amoruso et al., 2005).

Charter 6 presents regional scale vertical movements recorded by geodetic leveling data in the past 50-100 yr and by old geological paleoshorelines (D'Anastasio et al., 2006; Mancini et al., 2007). Conjuct analysis of geodetic, geologic-tectonic (paleoseismologic) and seismologic data allows to better constrain the interseismic deformation. The study of the active deformation at different time scales together with the comparison of the geodetic signal with the characteristics of the long-term deformation, derived from quantitative geomorphology, allow to better determine the seismic cycle in the Apennines.

Chapter 7 summarizes the main results obtained with the works done in the active zones of the Apennines. Moreover, our analysis of the active deformation of the Italian peninsula discusses the problem of a better definition of: the dimension of the active zones, the amount of tectonic stress, the area of recharge of this stress and their potential for the recrudescence of future seismic activity. In perspective, these studies allow us to identify and to better circumscribe the problem of the preseismic geodetic signal and to provide a realistic estimate of the seismic hazard in Italy.