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# Fault propagation in a seismic gap area (northern Calabria, Italy): Implications for seismic hazard

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ABSTRACT

The Crati basin is a tectonic depression developed between the Coastal Range and the Sila Massif and is characterised by a sedimentary succession ranging between Late Miocene to Holocene age. Basin cover can be subdivided into a series of stratigraphic intervals bounded by angular unconformities. The general basin architecture is mainly controlled by N–S striking normal faults (the Crati Fault System) cropping out along both basin margins. These faults formed since the Middle Pliocene in the southern part of the basin and propagated northwards, where they developed during Middle–Late Pleistocene.

The occurrence of several earthquakes along N–S striking faults, suggest their still ongoing activity. The northernmost part of the Crati basin, bordered by the 30 km long Pollino fault, is thought to be characterised by an important seismic gap; this contrasts with the geological evidences of Quaternary fault activation of both the central part of the Pollino fault and some NNW–SSE striking normal faults.

We propose that the NNW–SSE striking faults represent the northernmost prolongation of the Crati Fault System, a large scale active crustal rift related to the Tyrrhenian spreading. These faults mechanically interacted with the Neogene Pollino fault and determined the almost contemporary activation of the central part of this structure, because of stress triggering phenomena, as suggested by the Coulomb failure stress changes.

## 1. Introduction

Fault-growth by segment linkage is one of the fundamental processes controlling the evolution, in both time and the space, of rift systems. Step-like trajectories shown by length-displacement diagrams for individual fault arrays suggest that the development of evolved structures result by the linkage of single fault segments (e.g. Cartwright et al., 1995). In particular, although each fault segment shows a specific displacement ($D$)–length ($L$) ratio, the whole fault system behaves as a single structure in order to maintain the scaling relationship $D = \gamma L$, where $\gamma$ ranges between 0.001 to 0.1 for most rift systems (Schlische et al., 1996). The geometry of segmented structures, as demonstrated by previous works (Peacock and Sanderson, 1991; Cartwright et al., 1995), strongly influences the dispersal pattern of $D$–$L$ ratio along normal fault zones (Schlische et al., 1996; Marret and Allmendinger, 1990; Walsh and Watterson, 1998). Such a pattern, as observed in many rift zones around the world, also influences basin architecture and evolution, as well as basin depocentre variation along fault hanging walls, being the result of the different stages of interaction between neighbouring fault segments (Morley and Vonganan, 2000 and reference therein).

The type of interaction between faults and the rate at which faults reactivate not only control the long term tectonic evolution of an area, but also influence the seismic hazard, as earthquake recurrence intervals tend to decrease as fault slip rate increase. The use of palaeoseismological investigations represents an important tool to constrain the latest history of active faults; in this case, attention has to be given to the influence that the different location of trenches along the faults may have with respect to slip rate estimates. Moreover, approaching seismic hazard analysis using only information on historical earthquakes can be problematic because the recurrence interval of strong events in some instances may be longer than the historical seismic record of large normal faults. For this reason seismic hazard may be enhanced by considering how faults interact and grow (Cowie and Roberts, 2001; Roberts et al., 2004). Therefore, the integrated analysis of geological offset, geomorphic features (i.e. heights of fault scarps and/or triangular facets) and, when available, geodetic and trench-derived data, is one of the most reliable tool for seismic hazard investigations, allowing one to describe the evolution of fault activity during their lifetimes.

The aim of this paper is to investigate the active tectonics of the ~60 km long Crati basin (CB). By integrating geological and structural

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data with morphotectonic observations along mapped faults (i.e. the Crati Fault System), we describe their structural properties and their evolution both in space and time. The northernmost part of the CB is considered an area of apparent seismic gap; here the WNW–ESE oriented Pollino Fault Zone (PFZ) is thought of as being a silent fault (i.e. a fault not associated to historical or instrumental earthquakes but showing geological evidence of Late Pleistocene–Holocene activation), however NNW–SSE oriented active structures were recognised in the same area. Moreover, in order to discuss possible mechanical interactions between faults in this area we modelled the Coulomb failure stress distribution based both on original fieldwork and on information from previous palaeoseismological investigations (i.e. co-seismic fault displacement). This approach allowed us to investigate possible interactions between the Crati Fault System and the PFZ, with strong implications for seismic hazard assessment in this area of southern Italy.

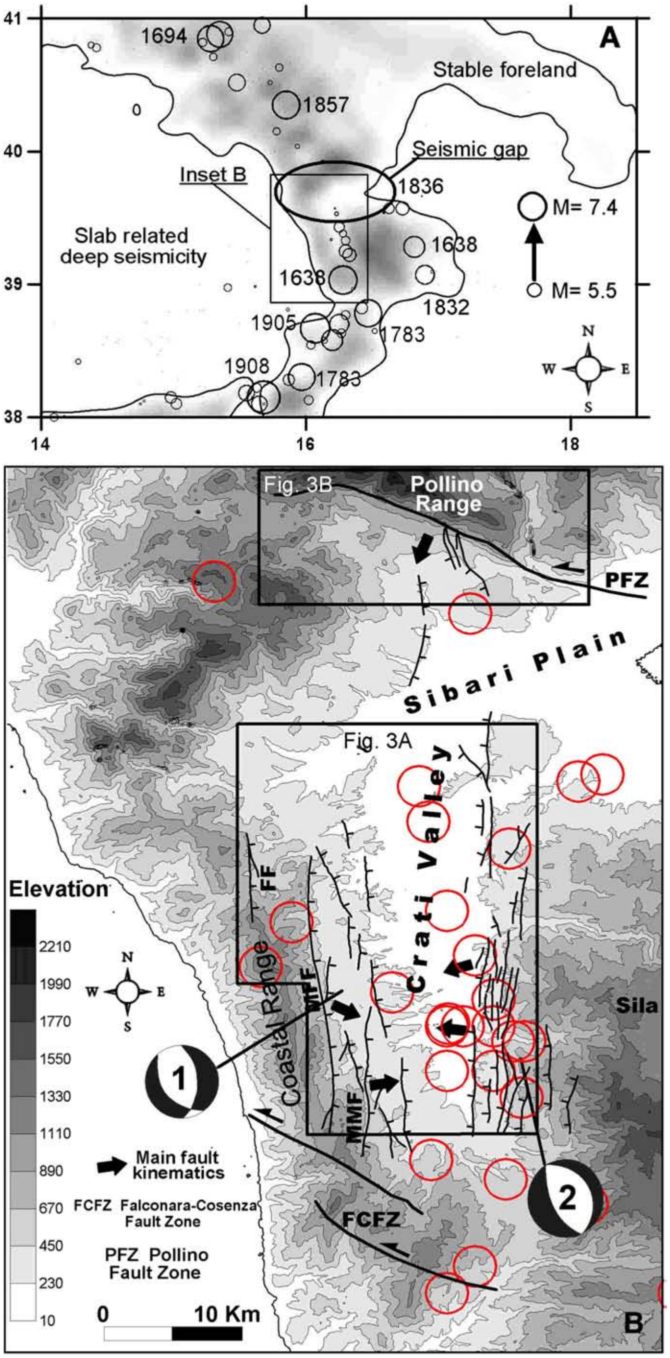

**Fig. 1.** Distribution of the seismicity. A) Historical seismicity (5.5<*M*<7.4) in the southern Apennines and northern Calabria (from CPTI, 2004) with the year of occurrence of the major earthquakes. Seismic events mainly characterise the internal sector of the chain with a distribution parallel to the fold and thrust belt. The trend of the events shows an interruption in correspondence of the PFZ. The lack of events between the southern Apennines and southern Calabria is thought to be a seismic gap. B) Seismicity distribution (3<*M*<7) in the CB. Focal mechanisms (modified from Galli and Bosi, 2003) testify the extensional character of active deformation: 1 refers to the 1st February 1980 earthquake (*M* = 4.3); 2 is the 6th October 2001 earthquake (*M* = 4.4). The seismic events cluster along the eastern side of the Crati valley and show a good fit with the Quaternary fault segments affecting this border of the basin (FF, Fagnano fault; MMF, S. Marco Argentano–S. Fili Fault; MRF, Montalto Uffugo–Rende Fault). Black arrows show mean kinematic vectors along faults.

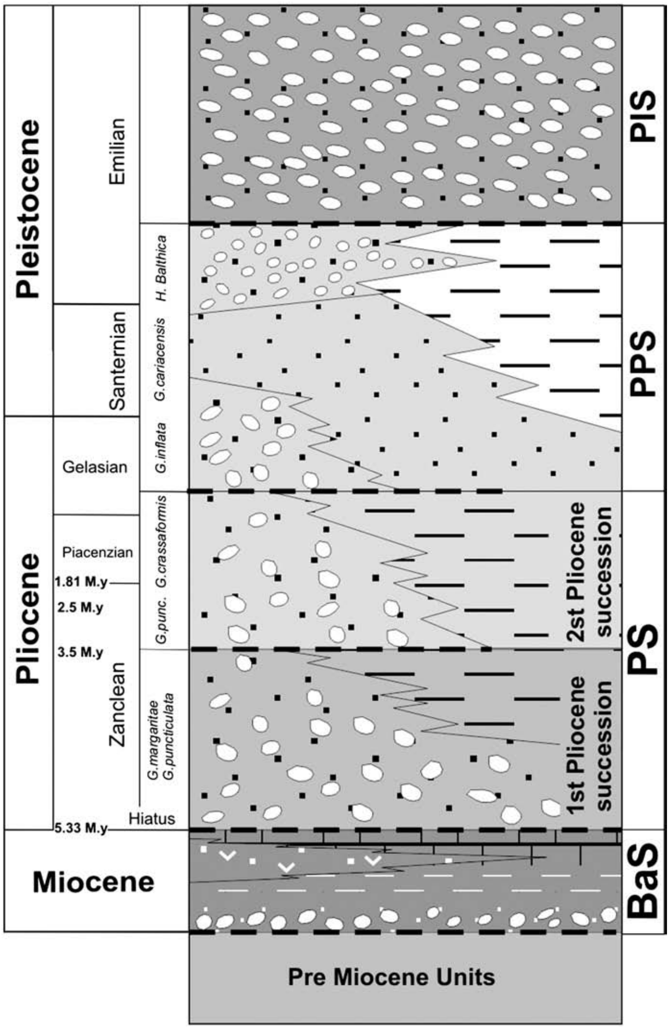

**Fig. 2.** Stratigraphic column for the Crati Basin, showing the main sedimentary units recognized in the basin. Thick dashed lines represent the principal angular unconformities between various units.

## 2. Seismotectonic background

In the southern Apennines most of the strongest historical earthquakes cluster along Plio-Quaternary normal to transtensional faults bordering large sedimentary basins in the axial zone of the chain (Fig. 1; Amato and Montone, 1997; Frepoli and Amato, 2000; Tondi and Cello, 2003; Galli et al., 2008). In north-western Calabria, the zone of active stretching is part of the so-called Siculo-Calabrian Rift Zone (Monaco and Tortorici, 2000), being mostly characterized by moderate historical seismicity (Fig. 1; CPTI, 2004). Extensional faults