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# Geodetic and geological evidence of active tectonics in south-western Sicily (Italy)

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ABSTRACT

Integrated geological, geodetic and marine geophysical data provide evidence of active deformation in south-western Sicily, in an area spatially coincident with the macroseismic zone of the destructive 1968 Belice earthquake sequence. Even though the sequence represents the strongest seismic event recorded in Western Sicily in historical times, focal solutions provided by different authors are inconclusive on possible faulting mechanism, which ranges from thrusting to transpression, and the seismogenic source is still undefined. Interferometric (DInSAR) observations reveal a differential ground motion on a SW–NE alignment between Campobello di Mazara and Castelvetrano (CCA), located just west of the maximum macroseismic sector. In addition, new GPS campaign-mode data acquired across the CCA alignment documents NW–SE contractional strain accumulation. Morphostructural analysis allowed to associate the alignment detected through geodetic measurements with a topographic offset of Pleistocene marine sediments. The on-land data were complemented by new high-resolution marine geophysical surveys, which indicate recent contraction on the offshore extension of the CCA alignment. The discovery of archaeological remains displaced by a thrust fault associated with the alignment provided the first likely surface evidence of coseismic and/or aseismic deformation related to a seismogenic source in the area. Results of the integrated study supports the contention that oblique thrusting and folding in response to NW–SE oriented contraction is still active. Although we are not able to associate the CCA alignment to the 1968 seismic sequence or to the historical earthquakes that destroyed the ancient Greek city of Selinunte, located on the nearby coastline, our result must be incorporated in the seismic hazard evaluation of this densely populated area of Sicily.



## 1. Introduction

Before the occurrence of the 1968 Belice seismic sequence (equivalent moment magnitude of the main shock ~6), the westernmost segment of the Sicilian Fold and Thrust Belt (hereafter, SFTB, Fig. 1) was considered a seismically quiescent region. Focal plane solutions proposed by authors in the last decades show controversial interpretations of the possible geometric and kinematic pattern of the 1968 seismogenic source. Computed focal solutions provide possible faulting mechanisms that range from thrusting on a WSW–ENE striking plane to right lateral transpression on a NNW–SSE striking plane (Mckenzie, 1972; Bottari, 1973; Gasparini et al., 1982; Anderson and Jackson, 1987; Frepoli and Amato, 2000). This ambiguity remains still unresolved due to the fact that the source of the 1968 earthquake sequence did not produce a typical seismic landscape (sensu Michetti, 2005) and that, as a result of low magnitude of the events, coseismic fault ruptures have never been observed until now. Moreover, recent deformation in this region has involved mainly clayey lithological units; consequently, exposed fault scarps along the epicentral zone of the 1968 earthquake are unlikely to be observed. For this reason, the identification and characterisation of seismogenic structures in south-western Sicily, and particularly within the Belice area (Fig. 2), has remained an open problem.

A correlation between instrumental and geological data was attempted by Monaco et al. (1996). The authors, based on geological and morphostructural analysis, suggested a NNW-dipping crustal

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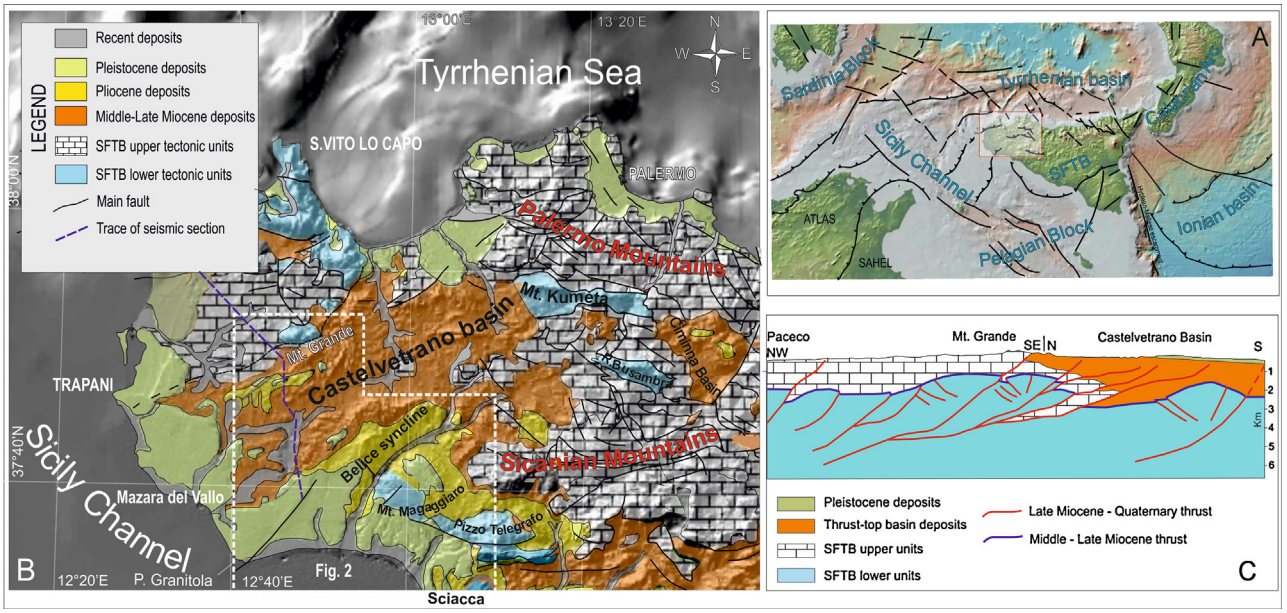


**Fig. 1.** (A) Tectonic model of the Central Mediterranean. Lines represent the main Quaternary faults, lines with triangles represent the main thrusts. (B) Tectonic sketch map of western Sicily. (C) Geological cross-section (see the trace in Fig. 1B) obtained by seismic interpretation (from Catalano et al., 1989, modified).

blind thrust ramp as the possible seismogenic source for the 1968 Belice earthquake sequence. Accordingly, Lavecchia et al. (2007) consider this area as part of a unique regional-scale seismogenic structure (named Sicilian Basal Thrust) which deepens northward from the front and reaches sub-crustal depths (see also Visini et al., 2010; Sgroi et al., 2012). Notwithstanding, these models do not provide precise constraints on the location and geometric character of the seismogenic sources in the area are.

In this paper, we present the results of a multidisciplinary study including interferometric and GPS data analysis, geological and morphostructural investigation, and marine geophysical survey that reveals recent and active displacement associated with a SW–NE alignment between Campobello di Mazara and Castelvetrano (CCA, Fig. 2) within the seismogenic zone where the 1968 Belice earthquake sequence occurred. The CCA and its eastern extension in the Belice valley are part of the frontal thrust belt in south-western Sicily and, as geodetic and archeoseismological data reveals, is the locus of active deformation that could be responsible for past destructive earthquakes.

## 2. Geological setting

Western Sicily (Fig. 1A) is a segment of the south-migrating SFTB, the emerged portion of a larger orogenic system (the Sicilian-Maghrebian orogen) which developed in the central Mediterranean region as result of the Neogene-Quaternary Africa-Europe collision processes (Dewey et al., 1989; Ben-Avraham et al., 1990). The SFTB is made up of a pile of thrust sheets deriving from the late Oligocene-middle Miocene deformation of the Neotethys ocean and of the Africa continental palaeo-margin (Bianchi et al., 1987; Roure et al., 1990; Bello et al., 2000; Catalano et al., 2000a,b).

The westernmost segment of the SFTB is a NE–SW oriented contractional belt including imbricates of Meso-Cenozoic carbonate platform and pelagic successions. The structural architecture of the belt is imaged by deep seismic explorations (Catalano et al., 2000a,b; Finetti et al., 2005) that show an upper, 1–3 km thick middle-Late Miocene fold and thrust system, which is superposed on a ~10 km thick thrust duplex, developed during the Plio-Pleistocene (Bello et al., 2000; Catalano et al., 2000a,b; Avellone et al., 2010; Barreca et al., 2010; Barreca and Maesano, 2012). Since late Miocene, deep-seated thrusting refolded and breached the previously stacked thrust imbricates and was accompanied by the development of syntectonic marine basins at the footwall of major structures (e.g. the Castelvetrano Basin, Fig. 1B and C). The top of the sedimentary succession is represented by Pleistocene terraced calcarenites, locally deformed by the frontal contractional structures.

In north-western Sicily, the inner portion of the deep-seated thrust system is characterised by the occurrence of high-angle thrusts and associated wide-wavelength folds (Avellone et al., 2010; Barreca and Maesano, 2012). Conversely, in south-western Sicily the frontal thrust faults show flat-ramp geometries (e.g. the Belice and Sciacca area, Fig. 1B), and are involved in lateral extrusion processes produced by the indentation of the orogenic wedge against the rigid part of the Pelagian foreland block (Fig. 1B; Monaco et al., 2000). Frontal thrusting is still seismically active, as indicated by the 1968 Belice Valley destructive earthquake sequence (Monaco et al., 1996; Morelli and Pondrelli, 1998; DISS Working Group, 2010). Accordingly, the seismotectonic processes accommodate active compression at the front of the SFTB and particularly along deep-seated thrust planes (Lavecchia et al., 2007; Visini et al., 2010; Sgroi et al., 2012).

At a more detailed scale, the structural setting of the studied area (Fig. 2) is characterised by NE–SW trending imbricate thrusts that propagated towards the foreland along Miocene to Quaternary sedimentary horizons. Thrusts propagation was accompanied by the development of large and gentle folds (e.g. Fiume Freddo anticline, Vita and Belice syncline, see Monaco et al., 1996 and Fig. 2). This shallow thrust and fold system appears trapped between the two structural culminations of Montagna Grande to the north, and M. Magaggiaro-Pizzo Telegrafo to the south (Fig. 1B, 2). The latter culmination originated from deep-seated thrusting that deformed part of the Pelagian foreland (Tortorici et al., 2001).

Recent tectonic activity is testified by folded Late Quaternary terraces and lacustrine deposits, outcropping at the frontal and shallower sector of the thrust and fold system, south of Pizzo Telegrafo. For a more detailed description of the recent tectonics in the Belice area, see Monaco et al. (1996).