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Deformation history during chain building deduced by outcrop structural analysis: The case of the Sicilian fold-and-thrust belt (Central Mediterranean)

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ABSTRACT

The Sicilian fold-and-thrust belt is located in the central Mediterranean area, and it represents the south-eastern arcuate segment of the Apennine-Maghrebide orogen. The tectonic evolution of the Sicilian belt is documented after outcrop analysis of small-scale structural features carried out throughout the region. Results are consistent with the following four main deformation stages having affected the study area, from the oldest to the youngest: (i) multilayer weakening; (ii) folding-and-thrusting, (iii) extension, and (iv) renewed thrusting. The first deformation stage included three different substages (layer-parallel shortening, bed-parallel simple shear and fold nucleation), the second one by both thrusting and fold amplification and tightening. The third deformation stage involved re-activation of the pre-existing mechanical discontinuities and formation of low-to-high angle normal faults. Out-of-sequence thrusting postdated the aforementioned extensional stage, and formed the latest orogenic deformation stage that affected the Sicilian belt.

1. Introduction

The kinematic evolution of orogenic belts is often difficult to decipher. In fact, the main problem consists of finding the linkage between the deformation history, which determines the chain building, and its significance in the context of lithospheric evolution dominated by plate collision. Moreover, the role of possible activation of pre-existing structural elements and the overprinting due to later deformation may further complicate the way in which to unravel the structural evolution of the wedge. Folding and faulting are the dominant mechanisms for strain partitioning during the chain building. The micro-to-macroscopic related structural elements, which cause the shortening accommodation in the shallow crustal levels during plate collision, are often geometrically and kinematically linked (Elliot, 1976; Berger and Johnson, 1982; Suppe, 1983, 1985; Williams and Chapmann, 1983; Suppe and Medwedeff, 1984; Jamison, 1987; Mitra, 1990; Chester et al., 1991). Furthermore, these elements may also be representative of distinct tectonic episodes (Crittenden, 1974; Geiser and Engelder, 1983; Van Der Pluijm, 1987; Hibbard and Hall, 1993).

The analysis of small-scale structural elements and their overprinting relationships is a successful approach applied by Butler (1992) and Gray and Mitra (1993) to decipher the complex deformation patterns, such as fold and thrust fault interactions (Chester and Chester, 1990). Worldwide, several studies focused on the deformative history during a single contractional episode (i.e. Nickelsen, 1979; Connors and Lister, 1995). For the Mediterranean region, several outcrop- and map-scale works documented the linkage between folding and thrusting during contractional deformation (Tavarnelli, 1997). However, regarding the Sicilian belt, a kinematic model including folding and thrusting and extension has not yet been documented.

Using overprinting mesoscopic fabrics and their relationships to larger structures, the aim of this paper is to provide constraints to help unravelling the structural evolution of the Sicilian chain. The orogenic building is made of several thrust sheets detached from the underlying basement during Miocene-Pliocene time interval, and progressively involved in a hinterland-to-foreland migration. The outcrop-scale structural elements are not uniformly distributed throughout the belt due to the multi-stage deformation that involved the multilayer from the hinterland (North of Sicily) to the foreland (South of Sicily). In order to better define the sequence of deformation, detailed structural analyses were carried out in key areas of northern Sicily, where, due to the mechanical

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behaviour of the outcropping rock, both ductile and fragile deformation features are present and well preserved. Furthermore, in the selected sites, the overprinting relationships among the small-scale structural elements are clearly exposed. Aiming at highlighting the spatial distribution of deformation, a quantitative analysis of some dimensional properties of meso-scale structural elements such as cleavage spacing, wavelength and amplitude of minor fold, thrust fault frequency and step-up angle, was performed on several sites from the hinterland to the foreland of the fold-and-thrust belt.

Our study demonstrates how the overprinting relationships between meso-scale structures, recorded in folded-and-faulted rocks, and their spatial distribution along the chain, can provide a powerful tool to unravel the evolution of map- and regional-scale structures of an orogenic belt.

2. Geological setting

Sicily is located in the Central Mediterranean, and it is considered as a part of the Tertiary Alpine-Himalayan suture zone. The Sicilian Thrust System (STS) is a south-verging fold-and-thrust belt made up of multiple thrust sheets that include Mesozoic-Lower Tertiary, pre-orogenic, multilayer sedimentary sequences. It represents the south-eastern arcuate portion of the Apennine-Maghrebides fold-and-thrust belt (Fig. 1). STS occupies the largest part of the island, involving stratigraphic sequences that display significant lateral facies and thickness variations (Catalano and D'Argenio, 1978, 1982; Nigro and Renda, 2000).

The thrust stack owes its origin to deformation of pre-orogenic strata originally deposited in different palaeogeographic domains of the Northern Africa passive margin (Fig. 2). The belt developed during Neogene times, following the closure of the Tethys Ocean and the continental collision between the Sardinia-Corse European block and the North Africa margin (Scandone et al., 1974; Catalano and D'Argenio, 1978, 1982). The thrust pile was detached from its underlying basement during Miocene-Pliocene time, and affected by faulting, folding and stretching. A general hinterland-to-foreland thrust propagation is recorded within the syn-orogenic deposits, which become progressively younger towards the foreland domain (Pescatore et al., 1987; Nigro and Renda, 2000).

Within the belt, three main structural provinces have been distinguished, from the inner sectors: The Peloritani range, the Maghrebide range and the Hyblean-Pelagian Block (Amodio Morelli et al., 1976; Catalano et al., 1978; Bianchi et al., 1987; Nigro and Renda, 2000; Monaco and De Guidi, 2006; Pezzino et al.,

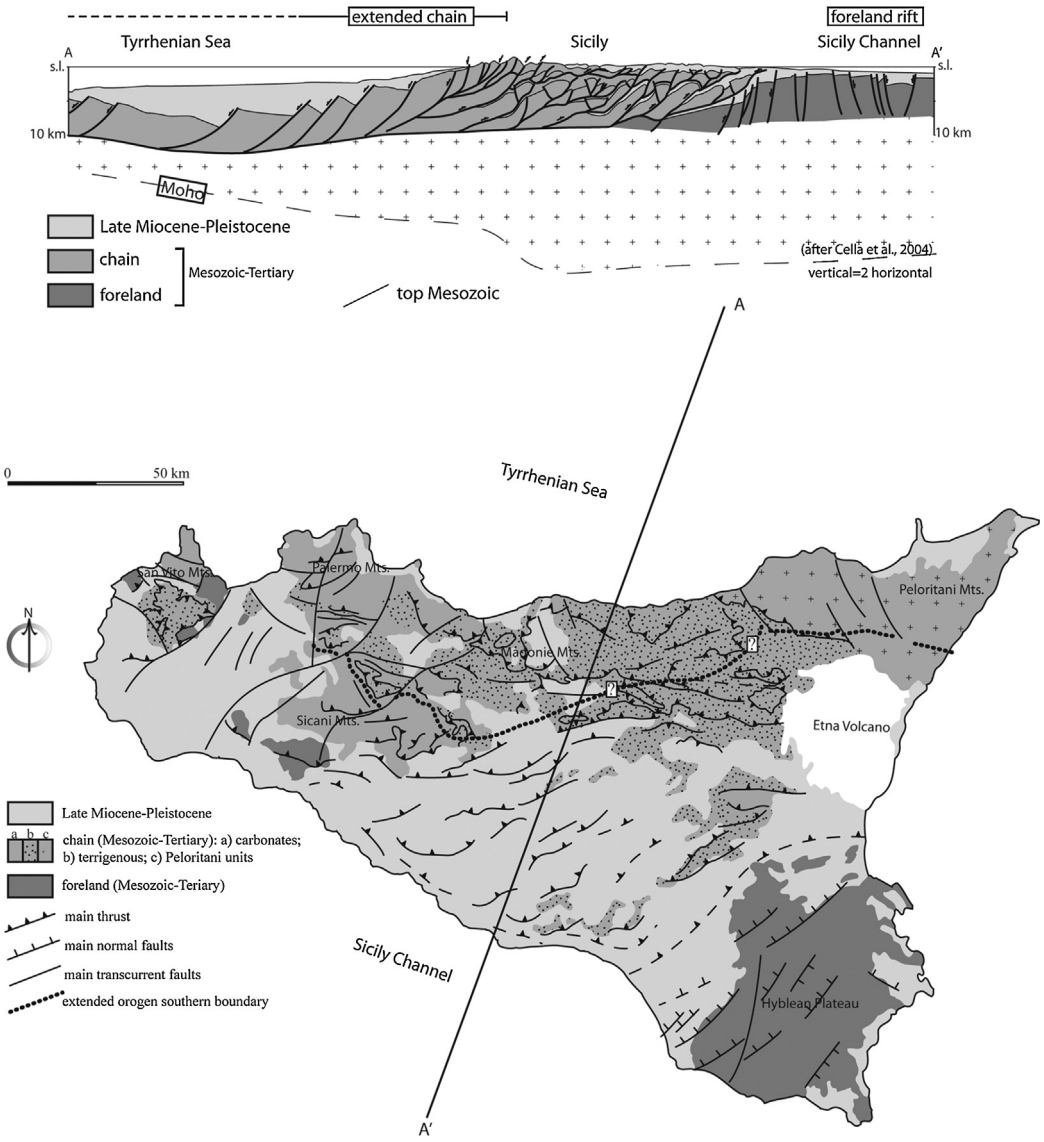

Fig. 1. Structural map of Sicily and cross-section Moho depth profile after Cella et al. (2004).