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Structural geomorphology, active faulting and slope deformations in the epicentre area of the M_W 7.0, 1857, Southern Italy earthquake

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ABSTRACT

In tectonically active domains, fault propagation processes are revealed by landforms. A characteristic morphological feature of exposed active faults is the occurrence of triangular facets. Triangle-shaped landforms morphologically similar to fault-related triangular facets result from erosion of moderately-to-steeply dipping strata or layered successions along fold limbs and are known as flatirons. Triangular facets and flatirons may commonly coexist in mountain chains resulting from the superposition of recent extensional faulting on inherited fold-and-thrust architecture. In these settings analysis of flatirons and triangular facets is not trivial and may result in geomorphologic misinterpretations, hence undermine the interpretations of the geological structure and related deformation history. Here we show that active fault lineaments can be discriminate by inherited morpho-structure. We present the combined results of photo-geological and field survey carried out along well-exposed triangular shaped landforms located in the seismically active Upper Agri River Valley of the Southern Apennine. We found that triangular shaped landforms develop along a major fold back-limb, the Mt. Lama western slope, making it possible to unequivocally interpret these as flatirons. Downslope, Mt. Lama back limb is affected by a large deep-sited landslide whose scarp bound the flatirons and mimics a Holocene fault scarp. This inference appears significant, since the investigated landforms were interpreted by many authors as triangular facets related to an active normal fault, located at its foot, responsible for large historical earthquakes (i.e., the 1857 earthquake). We provide new criteria to discriminate morphologic convergence in tectonically active domains, with consequences for the regional geological interpretation, and for the assessment of geological hazards.

1. Introduction

The Lucania Apennines, Southern Italy, are the result of the superposition of two tectonic phases. A compressive phase, Pliocene in age (Mazzoli et al., 2001; Ferranti et al., 2005), was followed by an extensional phase, Pliocene to Recent in age (Bucci et al., 2012). The compressive phase formed large regional thrusts and associated folds (Ferranti et al., 2005, and references therein), resulting in a fold-&-thrust-belt landscape. The successive extensional phase was mostly dominated by normal faulting, and resulted in a typical basin-&-range landform characterized by distinctive landform types, including horsts, grabens, and fault-related slopes.

Fold-&-thrust-belt (compressive) and basin-&-range (extensional) landforms can generate similar landform types, resulting in morphological convergence. In a fold-&-thrust-belt landform, where well-bedded sedimentary rocks are involved in kilometric-scale folds, flatirons can form along fold limbs bounding intra-mountain basins (Thornbury, 1954; Bartolini and Peccerillo, 2002; Burbank & Anderson 2012). A flatiron is a wedge-shaped, steeply sloping morphological feature formed by differential erosion of a resistant, layered rock dipping in the same direction than the slope (Bartolini and Peccerillo, 2002, and references therein). In a basin-&-range landform, along large fault-related slopes, active weathering, mass wasting phenomena and water runoff can rapidly erode closely spaced V-shaped valleys separated by fault spurs exhibiting a typical triangular shape. This landform type is known as triangular facet. A triangular facet is a V-shaped morphological feature formed by erosion on a steep slope. Although triangular facets are not limited to fault scarps, they are most abundant along fault-related mountain slopes (e.g., Wallace, 1977; Mayer, 1986; Dramis and Blumetti, 2005; Strak et al., 2010; Petit et al., 2010).

Despite their significant genetic differences, flatirons and triangular facets may be difficult to recognize, because of their morphological similarity. Both landform types exhibit a triangular, wedge-shaped form, and align in a distinct linear trend at the foot of a mountain front. Distinction between triangular facets, a fault-related landform, and flatirons, a fold-related landform, is further complicated where the metrics of surface faulting (rupture length

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and total vertical displacement) are comparable to the metrics of the main folds (wave and axial lengths). This is the case of the Lucania Apennines, and of other sectors of the Central and the Southern Italian Apennines. Where the two landform types are not properly recognized, analysis of flatirons and triangular facets may result in geomorphologic misinterpretations, with consequences on the geological interpretation of a region, and the associated geo-hazard assessment.

In this work, we show that flatirons and triangular facets can be distinguished in areas where morphological convergence exists. For the purpose, we present a case study from the Upper Agri River Valley (UARV), a seismically active area in the Lucania Apennines. In this area, a pelagic sequence pertaining to the Lagonegro Units, Triassic to Tertiary in age, was folded by the orogeny that built the Southern Apennines fold-&-thrust-belt. The folded sedimentary sequence was then dissected by post-orogenic normal faults responsible for the opening of the Upper Agri River Valley (UARV), and for strong historical earthquakes in the area, including the M_W = 7.0, 16th December 1857 earthquake. We first focus our analyses along the western slope of Mt. Lama (Fig. 1) where evidences of surface faulting were first recognized by Di Niro and Giano (1995) and were then attributed to the 1857 earthquake by Benedetti et al. (1998) and by Papanikolaou and Roberts (2007).

Despite the previous studies (Ferranti et al., 2007, and references therein), the geomorphological evolution of the western slope of the Mt. Lama remains poorly understood, and questions remain. We provide new data that contribute to answer some of the open questions, and in particular:

Are the morphological features located along the base of the western slope of Mt. Lama triangular facets indicating active normal faulting, or flatirons resulting from selective erosion?

Are the triangle-shaped landforms the result of post-orogenic bedding-parallel faulting, as indicated by Di Niro and Giano (1995)?

Is the 2.5 m high scarp described by Benedetti et al. (1998) evidence of surface rupture caused by the M_W = 7.0, 1857 earthquake?

To answer these questions, we collected new geological, geomorphological and structural data along the western slope of Mt. Lama. We further extend the investigation to the south, along the main Val d'Agri Fault System (VAFS) in order to collect kinematics and geometric information representative for the entire fault system. We conclude discussing the implications of our findings on the geological hazards in the study area, and in similar geo-structural settings along the Apennine chain.

2. Geological setting

The study area is located in the axial part of the Lucania Apennines, (Fig. 1), at the north-eastern margin of the UARV (Fig. 2). This area is dominated by exposures of the sedimentary rocks pertaining to the Lagonegro Basin domain (Fig. 3; Bucci et al., 2012, and references therein). These rocks comprise proximal and distal sediments deposited during the early stage of the Mesozoic continental rifting and the Cretaceous. During the late Oligocene to early Miocene continental collision (Patacca and Scandone, 2007), proximal and distal domains of the basin where stacked into two tectonic sheets; the proximal sequence overthrusted the distal ones. The study area is dominated by the Mt. Lama anticline. Along this regional fold structure, distal sediments pertaining to the Lagonegro Basin domain are exposed (Bertinelli et al., 2005a). These include: (i) the Calcari con Selce Formation (cherty

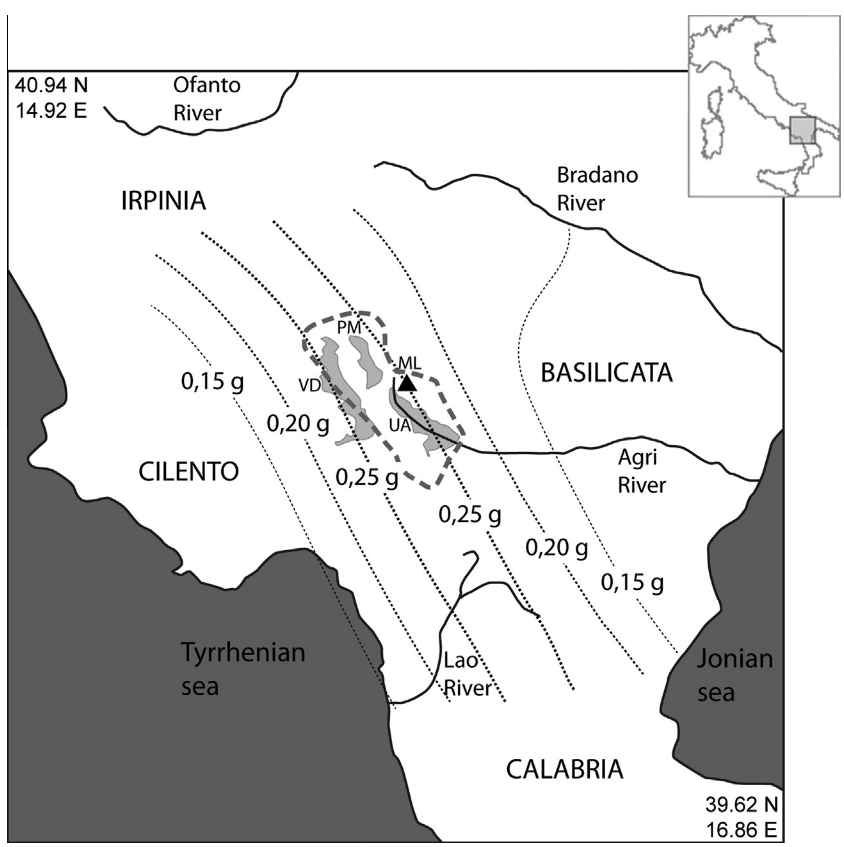

Fig. 1. Lucania Apennine, Southern Italy. Grey dashed line shows approximate location of the epicentre area of the M_W 7.0, 16 December 1857 earthquake. Dotted lines indicate seismic hazard in term of peak ground acceleration from the seismic hazard map of Italy available at http://zonesismiche.mi.ingv.it). VD, Vallo di Diano; PM, Pergola MelandroValley; UA, Upper Agri River Valley; ML, Mt. Lama.