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Quaternary, catastrophic rock avalanches in the Central Apennines (Italy): Relationships with inherited tectonic features, gravity-driven deformations and the geodynamic frame

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ABSTRACT

Five cases of Quaternary rock avalanches detached from carbonate mountain ridges in the Central Apennines are presented. Due to the large amount of rock masses involved, the width of accumulation and detachment areas and the damming in the host environment, the analysed rock avalanches can be considered as catastrophic rock slope failures, sporadic events in a mountain region characterized by low elevation but where mountain ridges can have a relative elevation of up to 1 km above the lowermost valley floors.

The geological setting of tectonic structures that originated during the Apennine orogenesis influenced rock avalanche characteristics, determining the location and shape of detachment areas, the kind of rock mass involved, and the failure mechanisms. Two main types have been identified: i) forelimb rock-slide avalanches (FRSA) such as the Lettopalena and Mt. Arezzo rock avalanche which involved Cenozoic, heterogeneous sequences of carbonate ramp deposits detached from box-shaped source areas according to a rock sliding mechanism; and ii) backlimb slide-wedge rock avalanches (BSWRA) such as the Campo di Giove, Scanno and Celano rock avalanches that detached from sub-circular source areas carved on fault-bounded ridges and involving Meso-Cenozoic carbonate rocks with a combined sliding and rock wedge failure mechanism.

The Campo di Giove, Lettopalena and Scanno rock avalanches originated from mountain ridges bounded by inactive fault zones and undergoing deep-seated gravitational slope deformations (DSGSDs) at the mountain scale. These three rock slope failures are considered as isolated events of long-lasting deformative processes featuring creep deformation. Gravity-driven deformations firstly generated as a response to stacking processes and synchronous normal faulting during the Neogene–Early Pleistocene Apennine tectonics. In particular, the Caramanico Fault System (CFS) and the Genzana Fault (GF), bordering the carbonate ridges from which the Campo di Giove and Scanno rock avalanches originated respectively, are here considered as backlimb collapse structures accommodating the passive uplift and deformation of positive tectonic structures. Gravity-driven deformations persisted during the post-Early Pleistocene dome-like uplift of the whole Apennine region. The regional uplift created the first-order (200 km) topographic wave-length of the belt, i.e. a periodic loading which has been balanced by the deflection of the Apennine crust and lithosphere. On the contrary, shorter topographic wave-lengths inherited from former thrusting and synchronous normal faulting determined local isostatic imbalances bearing a large potential for the mature development of DSGSDs on mountain ridges, favoured also by lateral unloading due to linear erosion and increase of topographic stress. Thus, a cause–effect relationship is hypothesized between the geodynamic evolution of the belt and mountain-sized gravity-driven deformations including large rock slope failures.

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1. Introduction

Rock avalanches originate from a massive flow of fragmented rocks that can move rapidly down a mountain slope. During a rock avalanche, the initial collapse from a rock slope is followed by expanding and shattering mechanisms that are responsible for spreading and run-out (Evans, 1989; Hungr et al., 2001; Legros, 2002; Evans et al., 2006). Clastic deposits may be found several kilometres far from their detachment areas and rocky debris may even move up the counterslope, sometimes exhibiting remarkable run-up (Hsu, 1975; Li, 1983; Evans, 1989; Nicoletti, 1989; Evans et al., 2004; Hungr and Evans, 2004; Davies and McSaveney, 2006; Evans et al., 2006; Hungr, 2006; Mangeney et al., 2010; Bowman et al., 2012).

In the Central Apennines several outcrops of Quaternary, continental clastic deposits have been identified to be remnants of rock-avalanche events (Nicoletti et al., 1993; Cinti et al., 2001; Paolucci et al., 2001; Di Luzio et al., 2004a; Scarascia Mugnozza et al., 2006; Bianchi Fasani et al., 2011a). They were found along mountain ridges made of carbonate platform, ramp and slope-to-basin deposits in the northern areas of the Central Apennines, whereas basin, clayey-carbonate deposits in the eastern and southern areas are rather prone to landslide and mudflow phenomena (Fig. 1).

We present in this paper five case-histories of huge, catastrophic rock avalanches: Lettopalena, Campo di Giove, Scanno, Celano and Mt. Arezzo (1–5 in Fig. 1). If compared to other mountain areas where hundreds of rock avalanches were observed, such as the Alps, Himalaya, and Andes (e.g. Plafker and Eriksen, 1978; Hermanns and Strecker, 1999; Strom and Korup, 2006; Korup et al., 2007), the Central Apennines are characterized by lower absolute elevation (rarely exceeding 2000 m). However, in the narrow (about 40 km-wide) axial zone of the belt (Figs. 1, 2) areas of high relief energy feature slope-to-valley systems where an elevation difference of up to 1 km – or even more – can be compared to that of much more elevated mountain areas worldwide. Therefore, the Central Apennines present favourable conditions for a localized occurrence of rock avalanches. Indeed, continental rock fall–rock slide debris that originated from rock slope failures are scattered throughout the Central Apennines (white dots in Fig. 1). However, these deposits cannot be attributed for certain to rock-avalanche events or compared to the case-histories presented in this paper in terms of: i) involved rock mass volumes, ii) extent of the accumulation areas, iii) and damming effects. The five rock avalanches we discuss in this paper can be considered as unique events in the mountain landscape of the Central Apennines.

In addition to the description of each rock-avalanche we discuss the interaction between these kinds of massive rock slope failures and the dynamics of rock slopes and the Apennine mountain belt. Rock avalanches can cluster along mountain slopes with Quaternary tectonic activity (Hermanns et al., 2001, 2006; Mitchell et al., 2007; Antinao and

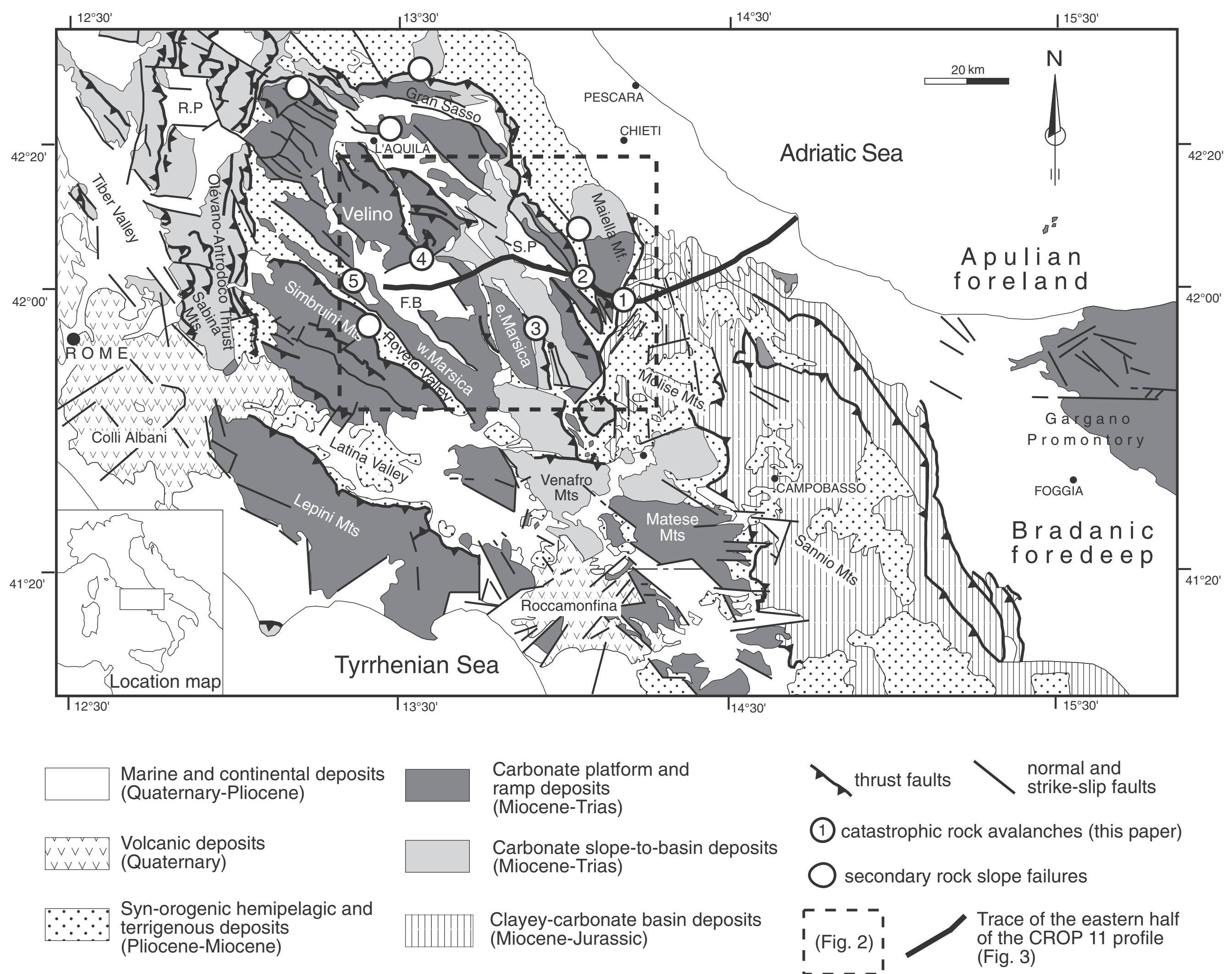

Fig. 1. Simplified geologic and structural map of the Central Apennines. Legend: 1) Lettopalena rock avalanche; 2) Campo di Giove rock avalanche; 3) Scanno rock avalanche; 4) Celano rock avalanche; 5) Mt. Arezzo rock avalanche; F.B. = Fucino Basin; R.P. = Rieti Plain; S.P. = Sulmona Plain.