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Interplay between mass movement and fluvial network organization: An example from southern Apennines, Italy

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ABSTRACT

Relationships between landslides and drainage network arrangement have been investigated by classical and quantitative geomorphological analysis in an intermountain valley (i.e. the upper valley of the Sinni River) of the southern Italian Apennines. The 120 km^2-wide test-area is characterized by very low grade metamorphic rocks (mainly shale) and associated crystalline-metamorphic rocks which underwent high exhumation and uplift rates during Quaternary times. We recognized and mapped 534 landslides through the stereoscopic interpretation of one set of 20 panchromatic aerial photographs 1:33,000 scale. Landslides were classified according to both type of movement and relative age. We detected and mapped 35 new landslides after a long rainfall period during the winter 2008–2009. The percentage of area affected by landslides (D_L) of the area has a high value (about 37%). Analysis of distribution of landslides areas within different age classes suggests that recent/present-day landslide distribution is strongly influenced by the legacy of widespread large and ancient landslides, probably generated within a different morpho-climatic setting. A quantitative geomorphological analysis of the drainage network has been performed to evaluate the influence of landslide processes on morphometric properties of the drainage network. In particular, the degree of hierarchical organization of the drainage network is assessed through the hierarchical anomaly density, a measure of the number of anomalous confluences (i.e. channels of u order not flowing in channels of order $u+1$) in drainage basins. On the basis of statistical relationships between morphometric indices of the drainage network and D_L, we argue that the activity of more recent mass movements rather than very old landslides can act as a disturbing element within the development of the drainage network, generating anomalous confluences of the 1st order. Empirical relationships between suspended sediment yield and some geomorphic parameters of the drainage network allowed the estimation of short-term denudation rates in the study area. The comparison between uplift and denudation rates suggests that the landscape system has not reached a steady state between uplift and erosion, in which tectonic uplift can represent a disturbing element within the recent morphogenesis. On the basis of the data presented, (large) mass movements in the study area are mainly linked to the relief growth promoted by Quaternary tectonics, whereas litho-structural and morpho-climatic factors assume a minor role.

1. Introduction

In the last decade, modeling in theoretical geomorphology has led to an emphasis on the role of fluvial processes in controlling landscape evolution of active orogens, especially in mid-latitude geomorphological environments (Whipple and Tucker, 1999; Willett and Brandon, 2002; Whipple, 2004; Bishop, 2007). Bedrock channels work to establish the landscape topography at orogen scale in response to tectonic uplift and climate changes (Snyder et al., 2000; Pazzaglia and Brandon, 2001; Whipple and Meade, 2006; Whipple, 2009) and set the lower boundary condition for hillslope processes (Whipple and Tucker, 1999). According to these concepts, hillslope processes and mass movements are promoted by base-level lowering and are often assumed to play a secondary role in mountain belt evolution, being related to short-time and local response to fluvial incision (Korup et al., 2010). In contrast, several recent studies demonstrated that large landslides can exert a strong control on relief evolution (Korup et al., 2010; Di Leo et al., 2011), drainage network arrangement (Mather et al., 2003; Azañón et al., 2005) and distribution of younger and smaller mass movement processes (Gioia et al., 2011a). Within the scientific literature, only a few studies examine the influence of landslide processes on morphometric properties of the drainage network. For example, Oguchi (1997) demonstrated a relationship between percentage of area affected by landslides (D_L) and drainage density in

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Japan. Ng (2006) examined the relationships between landslide distribution and drainage network evolution at the basin scale on the basis of the systematic variation between morphometric parameters and D_L. These works are largely based on the key approach that different stages of landscape evolution can be revealed by spatial variations in morphometric properties. Such an approach is also used in this work, where we tested and checked the influence of landslides of different ages on the spatial distribution of morphometric properties of the drainage network.

We present a detailed geomorphological study of a landslide-dominated landscape of southern Italy – the upper valley of the Sinni River (Fig. 1A) – characterized by landslides of different types, sizes, distributions, patterns, and triggering mechanisms, including some impressive (for the Apennines geomorphological environments) very old landslides. The upper portion of the River Sinni valley is characterized by a well-developed drainage network, showing typical features of a transient landscape (Schiattarella et al., 2006).

This contribution aims to qualitatively and quantitatively characterize the geomorphological coupling between fluvial and mass movement processes in an area where large landslides can have played an important role in landscape evolution. For this scope, a detailed landslide inventory map has been produced by classical (i.e. photo-geological interpretation and field survey) geomorphological analyses. Landslide appearance on aerial photographs was used to assess the relative age of the slope failures. Moreover, morphological cross-cutting relationships among landslide elements and between them and other geomorphic features were used to assess the relative chronology of landslide events within each age class. The statistical properties of the several generations of landslides recognized in the study area have been estimated according to

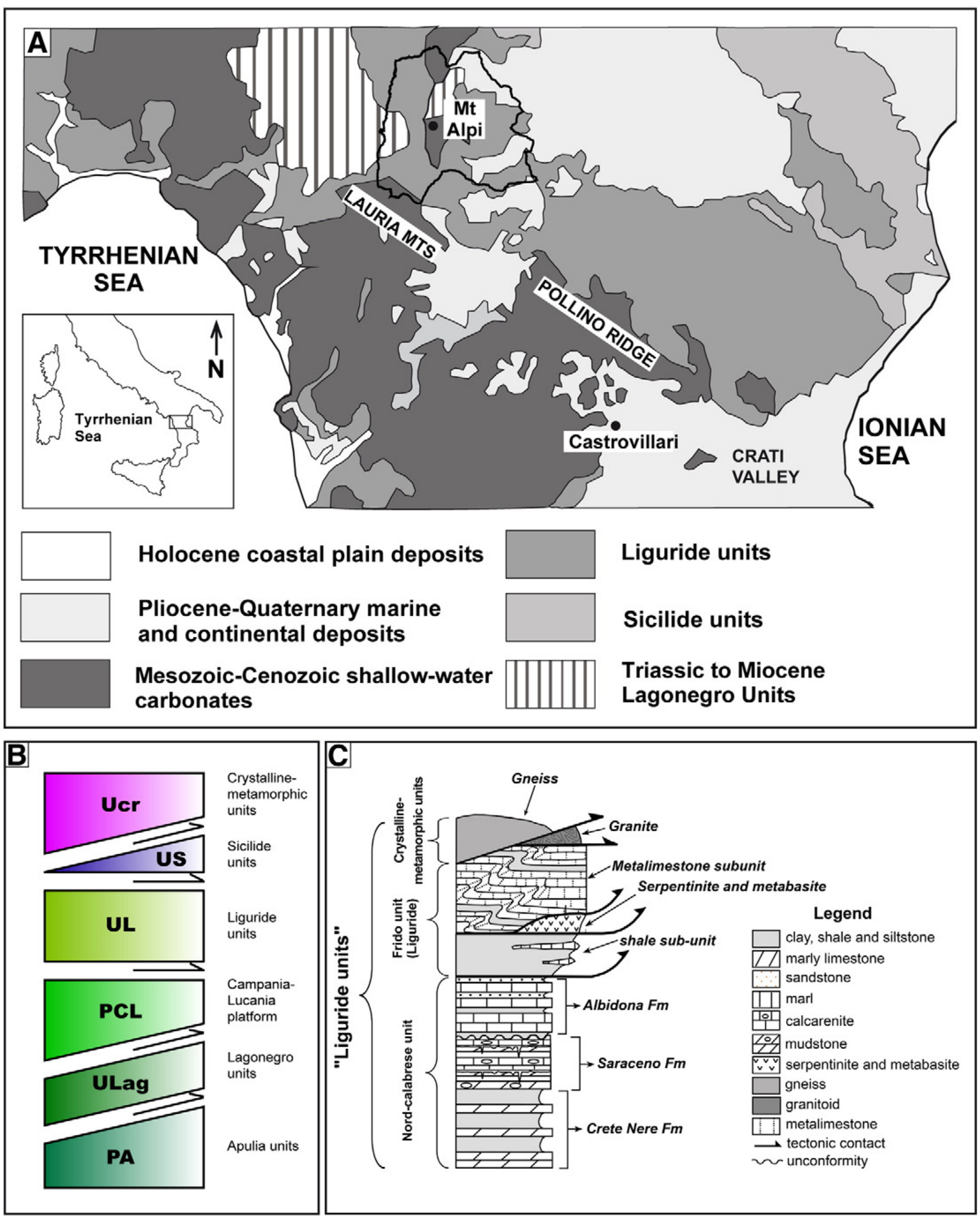

Fig. 1. Geographical and geological setting of the study area. (A) Location and geologic scheme of the southern Apennines (modified from Gioia and Schiattarella, 2006); (B) tectono-stratigraphic sketch of the Southern Apennines chain; (C) tectono-stratigraphic sketch of the internal units within the Southern Apennines chain (from Di Leo et al., 2005).