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Interdigitated fluvial clastic deposits and calcareous tufa testifying an uplift of the catchment area: An example from the Pianizzoli area (southern Tuscany, Italy)

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ABSTRACT

Calcareous tufa, as well as other types of continental carbonates, are largely sensitive to climate variations. As a consequence, the relationship between climate variations and tufa deposition is relatively well known and calcareous tufa deposits are often used as a reliable climatic proxy in many geological settings. Conversely, the response of tufa to tectonics and uplifting processes is relatively poorly known, due to their genetic independence from geothermally heated groundwater springs and associated tectonic-controlled upwelling conduits in tectonically active settings.

The aim of this paper is to describe a peculiar stratigraphic succession where calcareous tufa deposits are closely associated and interbedded with coarse-grained clastic deposits. The study area is located in southern Tuscany (Massa Marittima), where extensional tectonic processes, responsible for the emplacement of magmatic bodies at shallow crustal levels, have been active from Pliocene to Quaternary age, and caused a diffuse uplift as well as local volcanic eruptions and hydrothermal fluid circulation.

The succession described in the paper recorded phases of calcareous tufa-dominated deposition (i.e. overall, medium/low hydrodynamic energetic settings) repeatedly interbedded with coarse-grained clastic fluvial sediments which testify an abrupt change in both the energy of the depositional environment and the sediment supply. Nevertheless, during the phases dominated by clastic sedimentation, tufa deposition was not inhibited as it would be expected for climate-influenced settings, suggesting that the observed stratigraphic settings were a consequence of a local uplift of the catchment area.

These findings indicate that calcareous tufa deposits could be a sensitive proxy to tectonics when they are associated with coarse-grained clastic deposits, in a geological setting where the origin of the clastic sediments cannot be explained by autocyclic or climate-induced factors.

1. Introduction

Understanding the role of external driving forces (e.g. climate, eustasy and tectonism) on sedimentation patterns is of outstanding importance in sedimentary geology. This is emphasized in the study of Quaternary deposits, which commonly provide important elements to neotectonic and/or palaeo-climatic reconstructions. Distinguishing the effects of different forcing factors in ancient deposits however is often a difficult task to address. This is particularly true for continental successions, whose response to external driving forces is not always straightforward to understand (Schumm, 1977; De Wet et al., 1998; Blum and Törnqvist, 2000; Pla-Pueyo et al., 2009; Alonso-Zarza et al., 2012; Blum et al., 2013; Vázquez-Urbez et al., 2013).

Calcareous tufa deposits are a type of terrestrial limestones formed by precipitation of carbonate minerals from ambient-temperature water bodies (Ford and Pedley, 1996; Pedley, 2009; Capezzuoli et al., in press; Gandin and Capezzuoli, 2008). The deposition of tufa and related facies is common in many fluvial systems characterized by flowing waters which are rich in dissolved carbonate/bicarbonate and calcium (Arenas-Abad et al., 2010).

The close relationship between climate and tufa deposition has been widely evidenced (Pentecost, 2005; Andrews, 2006 and references therein). The presence of fossil tufa systems in sedimentary records testifies important climatic changes in the geological record. For example, rainfall availability is a key factor for tufa deposition as it sustains the groundwater flow and provides a carrier for the dissolved carbon dioxide. This intimate relation has been demonstrated in distal glacial transitional environments and for glacial periods (South Europe — Capezzuoli et al., 2010; Alexandrowicz, 2013) and in semi-arid (Brasil — Auler and Smart, 2001; Spain — Valero-Garcés et al., 2008; Luzón et al., 2011) and desert settings (Libya – Cremaschi et al., 2010; Ethiopia — Moeyersons et al., 2006). In the same way, the average air temperature is easily correlated to the extensive presence of forests that increased the supply of CO_2 in soils, thus enhancing the dissolution of carbonates and the saturation in calcite of karst waters after

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infiltration in suitable reservoirs. This highly-enriched carbonate water will subsequently precipitate in the vicinity of calcareous springs (Pentecost, 1995, Pentecost, 2005). In this view, warm climatic stages (especially during odd-numbered Marine Isotopic Stages — MISs) are preferential periods for tufa deposition as demonstrated in several Mediterranean (Horvatincic et al., 2000; Martín-Algarra et al., 2003; Ordoñez et al., 2005; Ortiz et al., 2009) and African examples (Hillarie-Marcel et al., 1986). As a consequence, specifically for non-tectonically influenced settings, tufas are a direct record of the wetter and warmer climatic phases and hence a key factor for local palaeohydrological studies.

The aim of this paper is to describe an uncommon stratigraphic setting exposed in the Pianizzoli area (Massa Marittima, southern Tuscany, Italy) in which fluvial coarse-grained clastic sediments are interbedded within an 80-meter thick Middle Pleistocene calcareous tufa-dominated succession. A similar lithological variation that testifies changes in fluvial depositional style and sediment supply is uncommon in tufa successions in temperate-to-semi arid climates, where conglomerates and/or sandstones are mainly developed at the base of the fluvial sequence (Arenas-Abad et al., 2010; Vázquez-Urbez et al., 2010). Only one similar example is described in arid settings in Namibia, where rapid hydroclimatic regime shifts provide a similar depositional sequence (Viles et al., 2007), whilst interbedded coarse carbonate grains/intraclasts generally occur more commonly within tufa successions (Pena et al., 2000; Arenas et al., in press).

Due to the high amount of vegetation in this area, rock exposures are uncommon. For this reason, the sedimentological and lithological analyses have been performed in a natural cave characterized by the general absence of drip water speleothems, whose presence generally prevents the possibility to observe the bedrock in caves (Martini, 2011; Iacoviello and Martini, 2012).

The distinctive succession in southern Tuscany described in this paper allows a review of external driving forces on tufa sedimentation patterns and the new interpretation that tufa deposition could be strongly conditioned by tectonic processes and not just by climatic parameter. This is an innovative concept in tufa studies, that has been marginally considered in deposition controlled by karst-related waters (Pena et al., 2000; Valero-Garcés et al., 2008; Garcìa-Garcìa et al., 2013; Arenas et al., in press) or, alternatively, where cool thermal-derived fluids and their related tectonically-driven springs are present (Corrêa et al., 2011; Brogi et al., 2012).

2. Geological setting

Southern Tuscany is located on the Thyrrenian side of the Northern Apennines (Fig. 1) and it is characterized by the occurrence of several Neogene/Quaternary-aged tectonic basins infilled by continental to marine deposits (Martini and Sagri, 1993 and reference therein). The basins rest unconformably on a pre-Neogene substratum made of tectonically juxtaposed units. Such pre-Neogene substratum, which lies on a metamorphic paleozoic basement (PB), is formed by non-metamorphic Mesozoic and Cenozoic units deposited in the Ligurian-Piedmont ocean (Ligurian Units — LU) and in the adjacent Adria continental margin (Tuscan Units — TU). Due to the almost complete subduction of the Ligurian-Piedmont ocean, the continental collision between Europe and Africa (started in the middle Eocene) brought to the development of the Northern Apennines thrust-fold chain (Vai, 2001).

In Southern Tuscany, the LU rests tectonically over the TU or locally on the PB directly, as a consequence of the extensional tectonic activity (Carmignani et al., 1994; Liotta et al., 1998), which acted since the middle Miocene (Brogi and Liotta, 2008; Barchi, 2010) and dissected all the previously orogenically-developed structures (Brogi, 2008) and produced significant stratigraphic elisions (Baldi et al., 1994; Bertini et al., 1994; Carmignani et al., 1994; Liotta et al., 1998; Brogi, 2006; Brogi and Liotta, 2008; Barchi, 2010).

High-angle normal and strike-slip faults have dissected the extensional detachments in Southern Tuscany since the Pliocene. These faults are of regional importance and their activity produced NNW–SSE trending Pliocene/Quaternary-aged basins filled by marine to continental sediments (Martini and Sagri, 1993; Capezzuoli et al., 2005; Pascucci et al., 2007; Martini et al., 2011, 2013).

Extensional structures developed contemporaneously to the emplacement of magmatic bodies at shallow crustal levels (Keller and

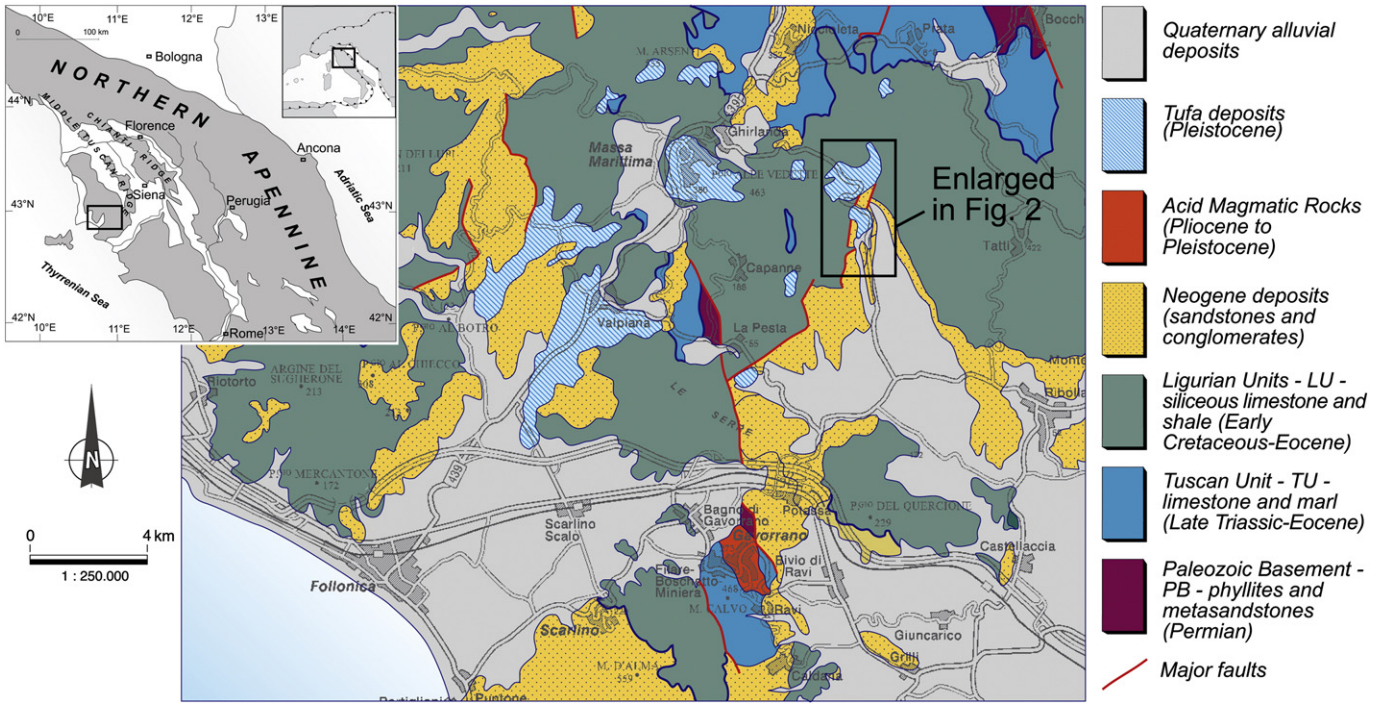

Fig. 1. Geographic location and simplified geological map of the Massa Marittima area.