Tectonophysics 690 (2016) 206–218

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Contrasting fault fluids along high-angle faults: a case study from Southern Apennines (Italy)

Rosa Sinisi [a,*], Angela Vita Petrullo [a], Fabrizio Agosta [a], Michele Paternoster [a,c], Claudia Belviso [b], Fausto Grassa [c]

[a] Department of Sciences, University of Basilicata, viale dell'Ateneo Lucano 10, 85100 Potenza, Italy
[b] National Research Council – Institute of Methodologies for Environmental Analysis, c/da S. Loja, 85050 Tito Scalo, Italy
[c] Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, via Ugo La Malfa 153, 90146 Palermo, Italy

ARTICLE INFO

Article history:
Received 29 October 2015
Received in revised form 28 April 2016
Accepted 23 July 2016
Available online 25 July 2016

Keywords:
Travertine
Mineralogy
Stable isotopes
Fault fluids
Southern Apennines

ABSTRACT

This work focuses on two fault-controlled deposits, the Atella and Rapolla travertines, which are associated with high-angle extensional faults of the Bradano Trough, southern Apennines (Italy). The Atella travertine is along a NW-SE striking, deep-seated extensional fault, already described in literature, which crosscuts both Apulian carbonates and the overlying foredeep basin infill. The Rapolla travertine is on top of a NE-SW striking, shallow-seated fault, here described for the first time, which is interpreted as a tear fault associated with a shallow thrust displacing only the foredeep basin infill. The results of structural, sedimentological, mineralogical, and C and O isotope analyses are here reported and discussed to assess the provenance of mineralizing fluids, and to evaluate the control exerted by the aforementioned extensional faults on deep, mantle-derived and shallow, meteoric fluids. Sedimentological analysis is consistent with five lithofacies in the studied travertines, which likely formed in a typical lacustrine depositional environment. Mineralogical analysis show that travertines mainly consist of calcite, and minor quartz, feldspar and clay minerals, indicative of a terrigenous supply during travertine precipitation. The isotope signature of the two studied travertines shows different provenance for the mineralizing fluids. At the Atella site, the $\delta^{13}C_{PDB}$ values range between +5.2 and +5.7‰ and the $\delta^{18}O_{PDB}$ values between −9.0 and −7.3‰, which are consistent with a mantle-derived CO_2 component in the fluid. In contrast, at the Rapolla site the $\delta^{13}C_{PDB}$ values vary from −2.7 to +1.5‰ and the $\delta^{18}O_{PDB}$ values from −6.8 to −5.4‰, suggesting a mixed CO_2 source with both biogenic-derived and mantle-derived fluids. The results of structural analyses conducted along the footwall damage zone of the fault exposed at the Rapolla site, show that the whole damage zone, in which fractures and joints likely channeled the mixed fluids, acted as a distributed conduit for both fault-parallel and cross-fault fluid migration.

1. Introduction

Travertines are the product of calcium carbonate precipitation in continental areas (Ford and Pedley, 1996; Pentecost, 2005; Pentecost and Viles, 1994), and are found worldwide in many different depositional, climatic, and tectonic settings (Andrews, 2006, and reference therein). In the last two decades, numerous studies of recent Quaternary travertine deposits demonstrated the close relationship between tectonic activity, fluid circulation and travertine formation (Altunel and Hancock, 1993a, 1993b; Ascione et al., 2014; Brogi and Capezzuoli, 2009; Brogi et al., 2010, 2012; Çakır, 1999; Hancock et al., 1999; Minissale, 2004; Özkul et al., 2002, 2010, 2013). In particular, the relationship between travertine deposits and extensional faulting documented by several authors suggest that these systems play a key role on hydrothermal and meteoric flow in the upper crust (Altunel, 2005; Arribas, 1995; Claes et al., 2015; Hancock et al., 1999; Henley and Adams, 1992; Kerrich, 1986; Norton and Knapp, 1977; Özkul et al., 2013; Rossetti et al., 2011; Shipton et al., 2004; Toker et al., 2015). To highlight the relationships between travertine formation and faulting, Hancock et al. (1999) coined the term "Travitonics", confirming the importance of travertines on documenting both regional and local tectonic regimes.

Travertine formation is also controlled by other factors, including climate (precipitation and temperature), hydrodynamics (pH, composition, and pressure of fluid), high CO_2 supply, and fast CO_2 degassing (Pola et al., 2014, and references therein). Mineralogy, geochemistry, and stable isotope signatures of travertines may provide a useful information on the paleo-environmental and paleo-climatic knowledge of a specific area (Altunel and Hancock, 1993a; Andrews, 2006; Chafetz and Folk, 1984; Guo and Riding, 1998; Jones and Renaut, 2010; Minissale et al., 2002). Many examples of multidisciplinary study addressing mineralogical, geochemical and isotopic analyses of travertine deposits are available in literature (e.g. Brogi and Capezzuoli, 2009; De

* Corresponding author.
E-mail address: rosa.sinisi@unibas.it (R. Sinisi).

http://dx.doi.org/10.1016/j.tecto.2016.07.023

Filippis and Billi, 2012; Faccenna et al., 2008; Fouke et al., 2000; Kele et al., 2011; Pentecost, 2005; Uysal et al., 2007, 2009). These investigations highlight that an integration of data from different disciplines is needed to identify the fluid pathways in the crust. In light of the aforementioned bibliography, in this paper we present sedimentological, structural, mineralogical, and stable isotope data of two fault-controlled travertine deposits of the Bradano Trough, the Plio-Pleistocene foredeep basin located at the outer front of the southern Apennines fault-and-thrust belt, Italy (Balduzzi et al., 1982). The studied deposits are located on the top of two different high-angle, extensional faults. One of them, the Atella Fault, a NW-SE oriented deep-seated fault, was already described in literature (Beneduce and Schiattarella, 1997; Giannandrea et al., 2004, 2006a; Schiattarella et al., 2005). In contrast, the NE-SW oriented shallow-seated Rapolla Fault is here documented for the first time. The present work is therefore aimed at identifying the provenance of the mineralizing fluids as well as deciphering the fault and fluid interactions. The goal is to evaluate the contrasting role exerted by deep-rooted and more shallow extensional faults on the fluid flow at shallow crustal levels beneath the front of the Apennine fault-and-thrust belt.

2. Geological setting and travertine occurrences

The study area is located at the outer front of the southern Apennines fold-and-thrust belt, along the western margin of the Bradano Trough (Fig. 1), which is the southernmost part of the Pliocene-Pleistocene foredeep basin (Bradano Trough, Patacca and Scandone, 2004). The southern Apennines consists of a buried, multi-duplex, NE-verging, rootless tectonic nappes comprised of Mesozoic-Tertiary terranes originally associated with the African-Adriatic margin, and syn-orogenic top-thrust deposits (Boccaletti et al., 1990; Casero et al., 1988; Patacca and Scandone, 1989, 2001; Patacca et al., 1990; Piedilato and Prosser, 2005). During the Early Pliocene, the entire pile of tectonic nappes overthrusted the carbonates of the Apulian foreland. At that time, NW-SE and NNW-SSE trending, high-angle, extensional faults formed due to bulging of the Apulian foreland in response to the northeastwards migration of the Apennine thrust sheets (Del Gaudio et al., 2007; Favali et al., 1990; Sella et al., 1990). During Middle-Late Pliocene times, the innermost domains of the Apulian carbonates were involved in contractional deformation due to thick-skin tectonics, whereas the allochthonous units on top were involved in extensional

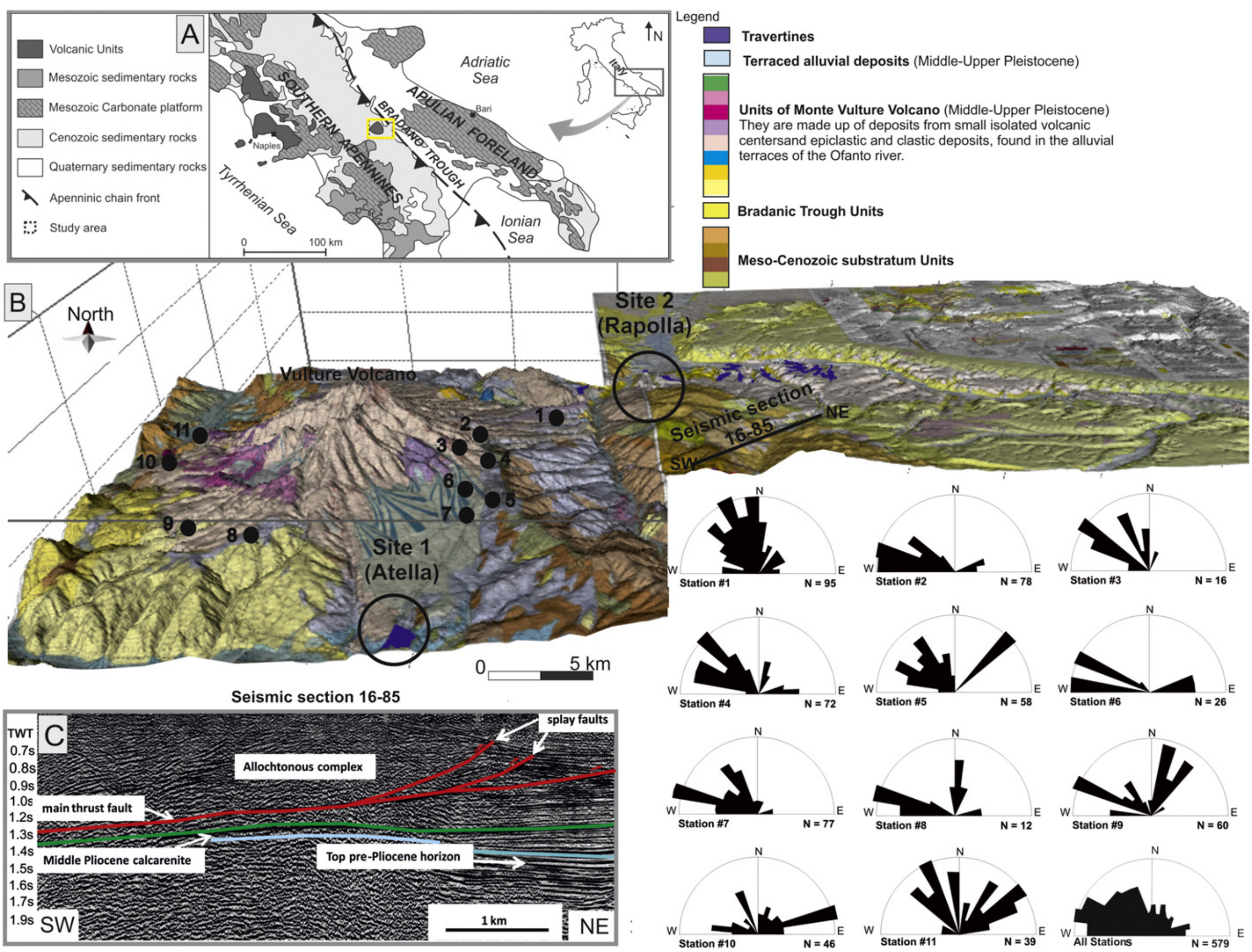

Fig. 1. 3D geological map, constructed using Move[TR] software, of the Vulture Volcano area (modified after Giannandrea et al., 2004). Location of measurement stations (# 1 to 11) and rose diagrams (bin size 10°, the outer circle corresponds to the 20% of cumulative data) of the high-angle fractures crosscutting the fluvio-lacustrine deposits and volcanic rocks are reported (modified after Schiattarella et al., 2005). On the bottom left is shown a public seismic reflection profile (www./unmig.sviluppoeconomico.gov.it), in which the main decollement and the splay thrust faults displacing the Pleistocene sedimentary succession are highlighted.