Quaternary Science Reviews 94 (2014) 74–101

Contents lists available at ScienceDirect

Quaternary Science Reviews

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

Major explosive activity in the Monti Sabatini Volcanic District (central Italy) over the 800–390 ka interval: geochronological–geochemical overview and tephrostratigraphic implications

F. Marra [a,*], G. Sottili [b], M. Gaeta [c,f], B. Giaccio [b], B. Jicha [d], M. Masotta [c,f], D.M. Palladino [c,f], D.M. Deocampo [e]

[a] Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, 00147 Rome, Italy
[b] Istituto di Geologia Ambientale e Geoingegneria, CNR, Montelibretti, Rome, Italy
[c] Dipartimento di Scienze della Terra, Sapienza-Università di Roma, Rome, Italy
[d] Department of Geoscience, University of Wisconsin–Madison, USA
[e] Department of Geosciences, Georgia State University, Atlanta, USA
[f] Bayerisches Geoinstitut, Universität Bayreuth, 95440 Bayreuth, Germany

ARTICLE INFO

Article history:
Received 21 January 2014
Received in revised form
27 March 2014
Accepted 9 April 2014
Available online 13 May 2014

Keywords:
Monti Sabatini Volcanic District
High-K magmatism
Geochronology
Geochemistry
Tephrostratigraphy
Central Italy

ABSTRACT

A review of the existing chronological, stratigraphic and chemo-petrologic data of the major eruptive units from the early phase of activity (800–390 ka) in the Monti Sabatini Volcanic District (MSVD), belonging to the ultra-potassic magmatic region of central Italy, is presented along with new radioisotopic age determinations and geochemical analyses. Through the combined use of electron microprobe glass compositions, selected trace-element compositions, and single-crystal $^{40}Ar/^{39}Ar$ age determinations, we provide a new chrono- and chemo-stratigraphic classification of the products emplaced in the 800–390 ka time interval. Besides giving insights on the petrologic evolution of the Roman Comagmatic Region, the large dataset provides fundamental information that is applicable to tephrostratigraphic studies in the wide region encompassing the Tyrrhenian Sea margin to the Adriatic Sea basin. Distal tephras from this volcanic activity also act as important geochronologic markers for the coastal sedimentary successions deposited in response to glacio-eustatic fluctuations, as well as for successions in the Quaternary tectonic basins of the Central and Southern Apennines. An innovative approach based on the use of discrimination diagrams of Zr/Y vs Nb/Y ratios for fingerprinting altered volcanic rocks – recently developed and successfully employed in archaeometric studies – is here combined to the glass compositions for classifying the MSVD deposits and tested on two distal tephra layers, showing its potentiality for tephrostratigraphic correlation.

1. Introduction

The recognition of distal tephra layers deposited in sedimentary successions and their correlation with proximal pyroclastic units are an important stratigraphic method. Tephrostratigraphy is in fact a pinpoint tool for a number of geological, paleoenvironmental and archaeological topics, providing a reliable control of the chronological framework (e.g. Lowe, 2011). The applicability and reliability of tephrostratigraphy are, however, subordinated to the depth of knowledge of the stratigraphy, chronology, petrology and major element glass and isotopic compositions of the proximal pyroclastic units. Indeed, without a reliable and robust reference dataset, tephrostratigraphy become an useless or even misleading chronostratigraphic tool.

The peri-Tyrrhenian high-K magmatic region, developed during the Pleistocene on the Tyrrhenian Sea margin of Central Italy (Peccerillo, 2005, and references therein), represents an important source of tephras due to the occurrence of intense explosive activity. However, with the exception of few notable cases of study (e.g., Colli Albani Volcanic District; Giaccio et al., 2013a), the lack of

* Corresponding author. Tel.: +39 0651860420; fax: +39 0651860507.
E-mail address: fabrizio.marra@ingv.it (F. Marra).

http://dx.doi.org/10.1016/j.quascirev.2014.04.010
0277-3791/

diagnostic data on proximal pyroclastic units limits most of these potential tephra sources for distal tephrostratigraphic purposes. This is particularly true for the Monti Sabatini Volcanic District (MSVD), whose eruptive history was dominated by frequent, highly explosive events up to at least 90 ka (e.g. Sottili et al., 2004, 2010). The mid-distal occurrences of the tephras from this volcanic activity provide important geochronological constraints for the coastal sedimentary successions deposited in response to glacio-eustatic fluctuations, like the Paleo-Tiber aggradational sections, which serve as an independent calibration of the oxygen isotope curves (Karner and Marra, 1998; Karner and Renne, 1998; Marra et al., 1998; Florindo et al., 2007; Marra et al., 2008). However, when dealing with very distal sedimentary successions, the correlation of given tephras to individual MSVD units is hardly tenable and often the correlation is, even if plausible, only hypothetic (e.g., Karner et al., 1999; Munno et al., 2001; Galli et al., 2010; Giaccio et al., 2013b).

In order to strengthen the potential use of the MSVD tephras for tephrostratigraphic purposes, in the present work we have combined field, geochronological and geochemical investigations to provide a detailed chrono- and chemo-stratigraphic framework of the main phase of activity spanning the 589–389 ka interval, integrating, and in some instances revising, the previous outline. Specifically, here we integrated the existing data (Conticelli et al., 1997; Sottili et al., 2004; Galli et al., 2010; Lancaster et al., 2010; Masotta et al., 2010; Marra et al., 2011, 2013) with new detailed chemo-chronostratigraphic investigations by bulk rock and electron microprobe (EMP) analyses, and $^{40}Ar/^{39}Ar$ age determinations. Following a recently developed methodology (Marra et al., 2011, 2013; Marra and D'Ambrosio, 2013), we also propose a classification of the altered MSVD mid-distal deposits by combining selected trace-element diagrams (i.e.: Zr/Y vs Nb/Y) with major element analysis, thus providing diagnostic criteria for establishing tephrostratigraphic correlations. In particular, we provide two case-histories by testing this method on two distal tephra layers collected in the Sulmona and in the Mercure lacustrine basins, occurring in the central and southern Apennines.

2. Stratigraphic setting

The MSVD is part of the Roman Comagmatic Province (Peccerillo, 2005, and references therein), a high-K magmatic region that developed during Pleistocene times on the Tyrrhenian Sea margin of Central Italy. The MSVD activity was characterized by K-rich magma composition, feeding dominant explosive eruptions ranging from hydromagmatic to Plinian and large pyroclastic flow forming events (VEI up to 4-5; Sottili et al., 2004), with erupted magma up to 10 km^3 for individual events, and subordinate effusive episodes.

The subject of the present paper is the MSVD ancient explosive activity, localized at the two source areas of Morlupo and Southern Sabatini. The climactic phases of this activity period spanned the interval 800–390 ka and are separated by a >100 ka-long, relative dormancy, from the following period occurring at the Bracciano and Sacrofano source areas (315 ka; Sottili et al., 2010). A late hydromagmatic phase, characterized by several monogenetic centers, occurred between 150 and 90 ka and represents the most recent volcanic phase in the MSVD (Sottili et al., 2010).

The oldest products attributed to the MSVD activity are represented by several tephra layers, sporadically intercalated within late Lower-early Middle Pleistocene fluvial deposits of the Paleo-Tiber River, dated between 802 ± 6 ka and 605 ± 11 ka[1] (Karner and Renne, 1998; Marra et al., 1998; Karner et al., 2001; Florindo et al., 2007). The vent area of these products is uncertain. A more continuous, extensive explosive phase of activity is documented by a thick succession of pyroclastic-flow and fallout deposits that constitute the Vulcani Sabatini Products (Scherillo, 1947; Mattias and Ventriglia, 1970: geologic map 1:100.000), cropping out above the Plio-Pleistocene sedimentary substrate over a ca 1500 km^2 area to the NW of Rome (Fig. 1). The early Plinian-style eruptions, emplacing fall levels and accretionary lapilli-rich ash layers (*Pyroclastic fall products from the Morlupo edifice*, de Rita et al., 1983, 1993), as well as a spatter-flow deposit (*Morlupo trachyte*, dated at 587 ± 4 ka; Cioni et al., 1993), whose stratigraphic relationship with respect to the other explosive products is unclear, have been attributed by de Rita et al. (1983) to the activity of the Morlupo center (Fig. 1). Subsequent explosive activity, responsible for the emplacement of the "Sacrofano lower pyroclastic flow unit" of de Rita et al., 1993 (corresponding to the "Tufo Giallo della Via Tiberina" of Mattias and Ventriglia, 1970; Alvarez, 1972, 1973; Nappi et al., 1979), was instead attributed to the activity of the volcanic center of Sacrofano (Fig. 1).

A first comprehensive geochronological framework and a revision of the stratigraphy for the MSVD were provided in Karner et al. (2001). Besides verifying an age of 582 ± 2 ka for the earliest fallout deposit (First Ashfall Deposits), these authors recognized a series of large pyroclastic-flow deposits erupted between 561 ± 2 and 514 ± 6 ka (Lower and Upper Tufo Giallo della Via Tiberina, Tufo Giallo di Prima Porta, Grottarossa Pyroclastic Sequence), that were previously grouped with the "Tufo Giallo della Via Tiberina" and the "Tufi stratificati varicolori di Sacrofano" (Mattias and Ventriglia, 1970). Moreover, Karner et al. (2001) introduced the "Tufi Terrosi con Pomici Bianche" pumice and scoria fall succession (488 ± 4 ka), which was investigated in detail by Sottili et al. (2004), who identified 3 major fallout horizons (Fall A, B and C) and attributed them, on the basis of the isopach and isopleth maps, to the Southern Sabatini volcanic center (Fig. 1). In the same way, based on the dispersal area of its basal fallout (Fall D, Sottili et al., 2004), also the large pyroclastic-flow forming eruption of the Tufo Rosso a Scorie Nere sabatino (Scherillo, 1940; Alvarez et al., 1975), dated at 449 ± 2 ka (Cioni et al., 1993; Karner et al., 2001), was attributed to this volcanic center. The late activity of the investigated volcanic period is represented by a succession of pumice and scoria fall deposits ("Tufi stratificati varicolori de La Storta", Mattias and Ventriglia, 1970; Corda et al., 1978) that underlie the Tufo Giallo di Sacrofano ("Sacrofano upper pyroclastic flow unit", de Rita et al., 1993) dated at 285 ± 2 ka (Karner et al., 2001). No direct geochronological constraint has been achieved so far for this pyroclastic succession, with the exception of two interbedded pumice fall layers, dated at 416 ± 12 and 410 ± 2 (Bedded Pumice, Karner et al., 2001), both identified in the present work as the Vico α fallout deposit (419 ± 3 ka, Laurenzi and Villa, 1987), from Vico volcano (Fig. 1). The lack of significant outcropping of deposits above and below the Vico fallout layers, corroborated by the occurrence of a thick paleosol documented by the present work on top of the 389 ± 4 ka San Abbondio ash-fall succession, suggests that a significant dormancy characterized the MSVD till ca 315 ka, when a new intense explosive phase of volcanic activity took place, causing the emplacement of the Tufo di Bracciano (316 ± 6 ka) and the Tufo Giallo di Sacrofano (286 ± 6 ka) major pyroclastic-flow deposits (Sottili et al., 2010).

3. Methods

3.1. Field investigations

Field investigations were carried out in the whole Monti Sabatini area (Fig. 1) to obtain an updated and comprehensive stratigraphic framework. A detailed description of the newly recognized

[1] $^{40}Ar/^{39}Ar$ mean weighted ages in this section are reported as they appear in the original publication. All ages are reported with 2σ analytical uncertainties.