Tephrochronology in faulted Middle Pleistocene tephra layer in the Val d'Agri area (Southern Italy)

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Abstract
The High Agri River Valley is a Quaternary Basin located along the hinge of the Southern Apennines fold-and-thrust belt. The inner margin of the orogen has been affected by intense transtensional and normal faulting, which accompanied vigorous volcanism during the Quaternary. Marker tephra layers are distributed across the whole of Southern Italy and provide a powerful tool to constrain both the size of eruptions and the regional activity of extensional faults controlling basin evolution. Paleoseismological trenching within the Monti della Maddalena range, that borders the Agri River Valley to the south-west, has exposed a faulted stratigraphic sequence and recovered a 10 cm thick tephra layer involved in deformation. This is the first tephra horizon recognized in the high Agri Valley, which, based on the stratigraphic study of the trench, lies in a primary position. 40Ar/39Ar dating constrain its age to 266 ka and provide an important marker for the Middle Pleistocene tephrochronology of the region. Together with dating, geochemical analysis suggests a possible volcanic source in the Campanian region.

**Key words** *tephra layer – $^{40}Ar/^{39}Ar$ dating – Southern Italy*

1. Introduction

The high valley of the Agri River (High Agri Valley, HAV in fig. 1) is a Quaternary tectonic depression located along the axis of the Neogene-Quaternary Southern Apennines fold-and-thrust belt (fig. 2). The HAV formed during Pleistocene-Holocene time in relation to the eastward extension associated to the opening of the Tyrrhenian Sea (Malinverno and Ryan, 1986; Hippolyte *et al*., 1995).

Mesostructural and geomorphological investigations along the Monti della Maddalena range to the west of the HAV have identified a 3.5 m high scarp which intercepts unconsolidated sediments, and this geomorphic feature likely represents the surface expression of a hidden seismogenic fault (Maschio *et al*., 2005). In fact, this area has been struck by destructive earthquakes, including the December 16, 1857 I_{max}=XI, *Me*=7 event (fig. 2; Working Group CPTI, 2004). Paleoseismological investigations have been performed along the easternmost portion of the scarp to identify evidence for recent slip. As a means to constrain timing of de-
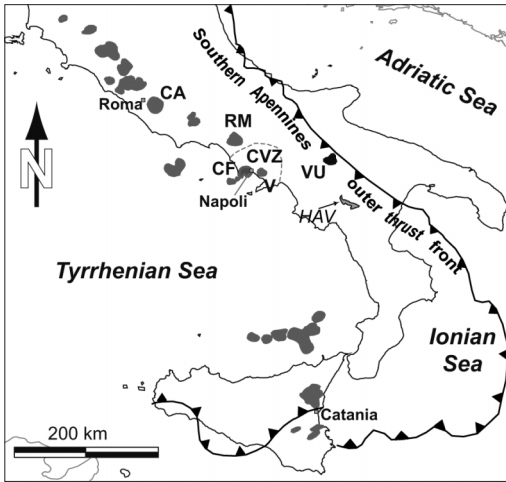
Fig. 1. Location map of the High Agri Valley (HAV) and distribution of the main volcanic districts along the central-southern Italy (dark areas). Key to abbreviations (from north to south): CA – Colli Albani; RM – Roccamonfina; CVZ – Campanian Volcanic Zone (within dashed line); CF – Campi Flegrei; V – Vesuvius; VU – Mt. Vulture; HAV – High Agri Valley.

formation, radiocarbon dating has been performed on faulted paleosols together with $^{40}Ar/^{39}Ar$ dating on sanidine samples from a recognized tephra horizon outcropping in the trench sequence.

Other tephra layers of Middle Pleistocene age from Southern Apennines have been previously studied (*e.g.*, Caggianelli *et al.*, 1992; Ciaranfi *et al.*, 1996; Bonadonna *et al.*, 1998; Karner *et al.*, 1999). This paper documents the first tephra layer found within the High Agri Valley, and as such helps place the valley in tectonic context with other basins found within the Southern Apennines. As a matter of fact, distal tephra layers are powerful tools for regional lithostratigraphic correlations and can be used to constrain the timing of regional tectonic-sedimentary processes. The geochemical signatures from different volcanic provinces make it possible to discriminate among sources for these distal tephra layers, although this geochemical characterization is not yet sufficiently complete to unambiguously correlate individual horizons to volcanic sources in Southern Italy.
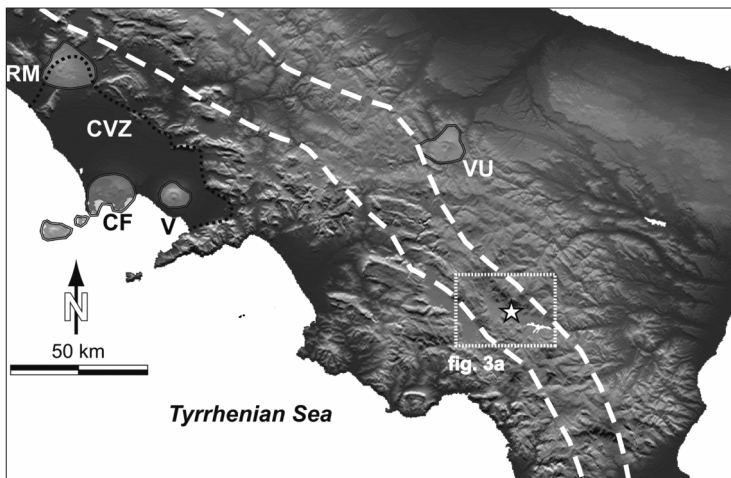
Fig. 2. Location of the HAV within the Southern Italy seismic belt. The star locate the epicentral area of the *M* 7.0 1857 earthquake (Working Group CPTI, 2004). The main volcanic districts closer to the HAV are highlighted (same abbreviations as in fig. 1). Note that besides the Mt. Vulture (VU), they all are located along the inner Tyrrhenian margin of the Southern Apennine fold-and-thrust belt. The dashed white lines indicate the Southern Italy seismic belt (*i.e.* the area where the maximum seismic moment is released). Dotted line indicate the distribution of CVZ products (Rolandi *et al.*, 2003).

Considering the importance of documenting tephrochronology histories in the Southern Apennines to constrain the timing of basin tectonism, we present a study of the tephra layer recovered in the trench. We suggest possible sources for this layer, but acknowledge that more information is needed before unambiguously correlate it with its eruptive source.

2. Volcanism of central-southern Italy

During the Pliocene-Pleistocene extensional tectonics, volcanic activity occurred along the Eastern Tyrrhenian margin, at the intersection between NW-SE- and NE-SW-trending faults (Beccaluva *et al*., 1989). The NW-trending, Quaternary to Recent volcanic belt was characterized by explosive activity which produced eruption columns which were dispersed downwind. The related distal tephra layers, which can be found interbedded within continental and marine deposits, represent distinctive chronostratigrahic markers in the successions and provide a means to study relationships among volcanism, regional tectonic, sedimentary and paleoclimatology processes.

The volcanic districts of central-southern Italy are grouped into the Roman Comagmatic Province (RCP; Washington, 1906) which includes the eruptive centers in Southern Tuscany and Latium, such as Sabatini, Vico, Vulsini, Colli Albani, Ernici and Roccamonfina districts, and the Campanian Volcanic Zone (the Campi Flegrei-Procida Island, Ischia Island and Somma-Vesuvio complex) (figs. 1 and 2). Mt. Vulture is the only volcanic complex located east of the Apennine Chain (fig. 2).

Volcanic products of the RCP range in composition from shoshonitic basalts to trachy-phonolites (potassic series) and from basanites and leucitites to phonolites (ultrapotassic series) (Appleton, 1972). At Roccamonfina volcano, both series are represented.

The Roccamonfina, the Campanian volcanic centers and the Mt. Vulture volcano, located at about 200, 150 and 80 km, respectively, from the HAV trench site, represent the most proximal areas (fig. 2). Large volumes of pyroclastics were erupted from all of these districts.

Roccamonfina's deposits have a distribution limited mainly to the northern sectors of the Campanian region while volcanoclastic products related to the youngest activity phase of the Colli Albani district (Peperino Albano Ignimbrite, 30 ka; Giordano *et al.*, 2002) have been recognized in the lacustrine sediment record of Lago Grande di Monticchio inside the Mt. Vulture crater (Wulf *et al*., 2004). High magnitude events took place, particularly in the Campanian region during the Pleistocene as testified by the occurrence of several tephra layers in the stratigraphic record of the Tyrrhenian and Eastern Mediterranean Sea (Keller *et al*., 1978; Paterne *et al*., 1986, 1988; Narcisi and Vezzoli, 1999; Rolandi *et al*., 2003).

In order to better constrain a possible source area for the sampled tephra, we briefly present the principal periods of activity and the main petrologic and volcanologic features of these three volcanic areas.

2.1. *Campanian volcanic zone*

The Campanian volcanoes are the most recent and still active volcanic areas of the RCP. The Campi Flegrei-Procida Island and Ischia Island products belong to the potassic series and more than 90% of these is constituted by evolved rocks (trachytes and phonolitic trachytes; Di Girolamo *et al.*, 1984; Rosi and Sbrana, 1987). Sanidine is the most abundant phenocryst and microphenocryst phase.

The Vesuvius products can be grouped into the high potassium series (HKS; Appleton, 1972) and they are represented by leucite-bearing basanites to phonolites. Less undersaturated potassic rocks were erupted by Somma-Vesuvius during the first phase of its activity >17 ka (Santacroce, 1987).

The beginning of activity at Campi Flegrei and Somma-Vesuvio complex has been dated at about >60 ka and 400 ka, respectively (Brocchini *et al*., 2001; Pappalardo *et al*., 2002). Ages older than 150 ka have been found in the lowest pyroclastic products of Ischia Island (Poli *et al.*, 1987).

Ancient explosive activity in the Campanian Volcanic Zone seems to be testified by several

trachytic ignimbrites dated at 205 ka, 184 ka and 157 ka (De Vivo *et al.*, 2001). Furthermore, an experiment carried out on a xenocryst yielded an age of 315 ka (De Vivo *et al.*, 2001). The older ignimbrite deposits where dated at 290 to 246 ka (Rolandi *et al.*, 2003). These eruptions largely predate the Campanian Ignimbrite (37.1 ka, Deino *et al.*, 1992; 39 ka, De Vivo *et al.*, 2001) which represents one of the largest event in the Mediterranean region during the last 200 ka.

2.2. *Roccamonfina*

The Roccamonfina strato-volcano is formed mostly by leucite-bearing, High-K Series (HKS) lavas and tephra. Low-K Series (LKS; Appleton, 1972) products are often associated with HKS deposits in several parasitic centers. The main cone of the volcano started to form during the 549-374 ka BP leucite-bearing HKS Stage I while during the 317-96 ka BP leucite-free LKS Stage II the parasitic vents formed. An intermediate phase with concurrent HKS-LKS products, occurred between 376-323 ka BP (Giannetti and De Casa, 2000; Giannetti, 2001). During this period a large ignimbrite formation (385-335 ka BP, Brown Leucitic Tuff; Luhr and Giannetti, 1987) was erupted after the collapse of the central and northern calderas. A sequence of trachytic pyroclastic flows and surge deposits with very minor Plinian pumice fall-outs, namely White Trachytic Tuff (WTT) (Giannetti and Luhr, 1983), erupted over an interval of nearly 100000 years (317 ka-230 ka BP) during small-volume (about 1 km^3 for each member) explosive eruptions (Giannetti and De Casa, 2000).

2.3. *Mt. Vulture*

The Mt. Vulture strato-volcano is the easternmost district of the Roman Magmatic Province and it is located at the western border of the Adriatic-Bradanic foredeep (La Volpe *et al.*, 1984). This peculiar structural setting accompanies a distinctive composition of magmas, which are characterized by both K and Na enrichments, together with a significant presence of extremely silica-under saturated melilite-bearing products (Melluso *et al.*, 1996). The eruptive history of the Mt. Vulture has been divided into three main phases which cover a time-span ranging from 800 ka to 130 ka (740 ka, 600-500 ka, 132-133 ka; Brocchini *et al.*, 1994). During the initial phase of volcanic activity (Laurenzi *et al.*, 1993), trachyphonolitic pyroclastic falls and flows with lava blocks and domes were erupted. The second (Broc-chini *et al.*, 1994) and third (Guest *et al.*, 1988; Stoppa and Principe, 1997) eruptive phases were characterized by pyroclastic and lava flow deposits of a generally mafic composition (tephrite, phonotephrite, basanite; Beccaluva *et al.*, 2002), with some carbonatitic lapilli tuffs interbedded within the most recent deposits of the Monticchio tephra (Stoppa and Woolley, 1997). Phreatomagmatic activity, typically found in the younger period, formed the Monticchio lakes.

3. Tectonic and geologic setting of the Val D'Agri

The High Agri Valley is a Quaternary tectonic depression located in the axial portion of the Southern Apennines (fig. 2). Starting from the Late Miocene, back-arc extension related to the opening of the Tyrrhenian Basin affected the inner portion of the chain, and migrated eastward at the rear of the compressional fronts (Malinverno and Ryan, 1986; Hippolyte *et al.*, 1995). During Early Pleistocene, strike-slip faulting affected the chain, and formed intermontane basins, such as the High Agri Valley and the Vallo di Diano (fig. 3a; *e.g.*, Karner *et al.*, 1999; Giano *et al.*, 2000). Starting from Middle Pleistocene, high-angle normal faults controlled formation of accommodation space and sedimentation within the basins (Cinque *et al.*, 1993; Hippolyte *et al.*, 1994). At the same time, to the west, crustal thinning led to volcanism along the Tyrrhenian margin (*e.g.*, Barberi *et al.*, 1994).

In the HAV, recent to ongoing extension is considered to be accommodated by a newly formed NE-dipping fault system located within the Monti della Maddalena range to the west of the valley (MMFS in fig. 3a, Maschio *et al.*, 2005).

Morphologically, the HAV follows an arcuate NNW- to WNW-trend (fig. 3a). The basin is
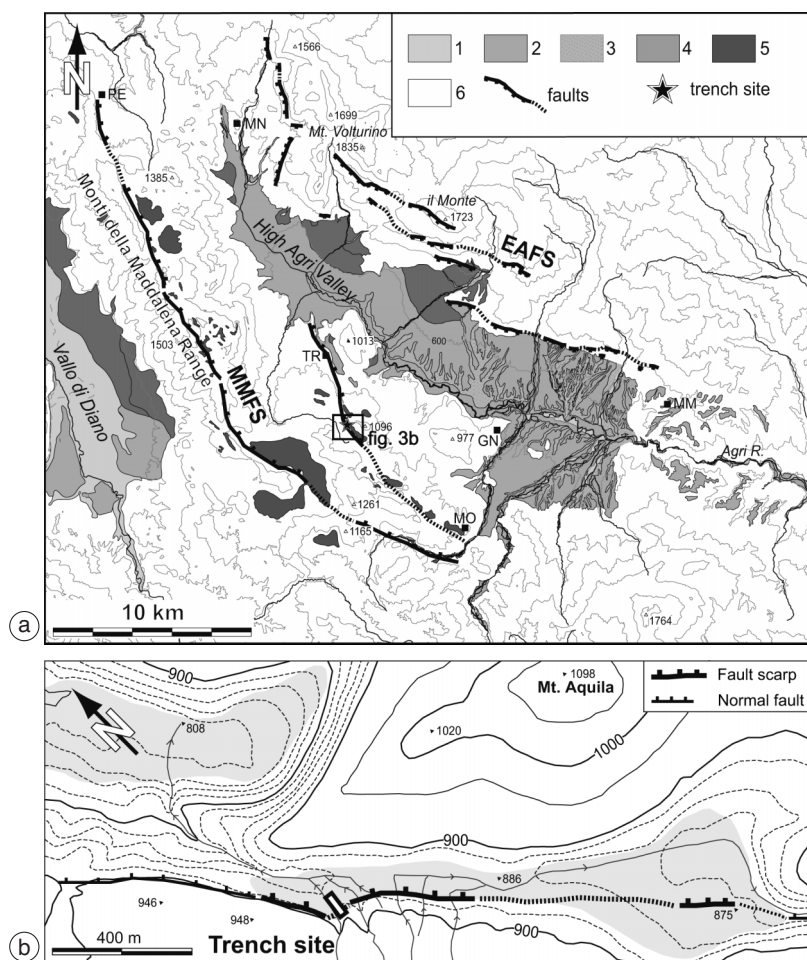
Fig. 3a,b. a) Morphotectonic map of the High Agri Valley, showing the main Quaternary morphological features, recent fault systems (traces of the Monti della Maddalena Fault System- MMFS and of the East Agri Fault System-EAFS after Maschio *et al.*, 2005), drainage network and topography (contours every 100 m). Key to symbols: 1 – Holocene alluvial plain; 2 – Middle Pleistocene alluvial deposits; 3 – middle Pleistocene «Complesso Val d'Agri»; 4 – Pleistocene-Holocene slope deposits and alluvial fans; 5 – Quaternary intra-mountane basins filled with lacustrine and colluvial deposits; 6 – Pre-Quaternary bedrock. Towns: MN, Marsico Nuovo; TR, Tramutola; GN, Grumento Nova; MO, Moliterno; MM, Montemurro. b) Detail of the eastern branch of the Monti della Maddalena Fault System (MMFS, Maschio *et al.*, 2005). Along this 2 km-long section, young colluvial deposits are displaced by 2-3 m high normal fault scarps. The paleoseismological trench has been dug across an E-W-trending relay connecting two left-stepping an-echelon fault scarps. Recent basins filled with alluvial and wash deposits are aligned along the fault, and are highlighted in light-gray.

axially drained to the southeast by the Agri River, which forms in an up-stream section a wide active alluvial plain deeply incised towards the basin threshold. Close to the basin threshold,

three orders of terraces are entrenched into the Middle-Upper Pleistocene age sedimentary sequence (fig. 3a). Numerous small perched Quaternary basins, filled with lacustrine and slope

deposits, align along the topographic crest of the Monti della Maddalena range, and may be considered the surface expression of the active tectonic fault system (Maschio *et al.*, 2005; fig. 3a).

4. Stratigraphy sequence at the trench site

A 40 m-long, N-S trending trench was excavated on an E-W bend of the 2 km-long, NW-SE trending main fault scarp (MMFS in fig. 3a), where it intersects young unconsolidated deposits (fig. 3b; Maschio *et al.*, 2005) (Coordinates: Lat 15.802, Long 40.289). Paleoseismological techniques principally consist of identify-

ing deformation in the surface emergence of a seismogenic fault. In this study, the detailed reconstruction of the stratigraphy sequence exposed along the 3 to 4 m-high vertical walls of the trench, has distinguished some of the geological records of past large earthquakes which have affected the High Agri Valley. The trench walls were logged in detail to evaluate structural and stratigraphic relationships exposed by the excavation. The stratigraphy has shown a sequence of young colluvial soils rich in volcaniclastic materials, downfaulted against the bedrock composed of Mesozoic argillite and limestone. We therefore detail part of the more complete stratigraphic sequence to which the deformed ash layer be-
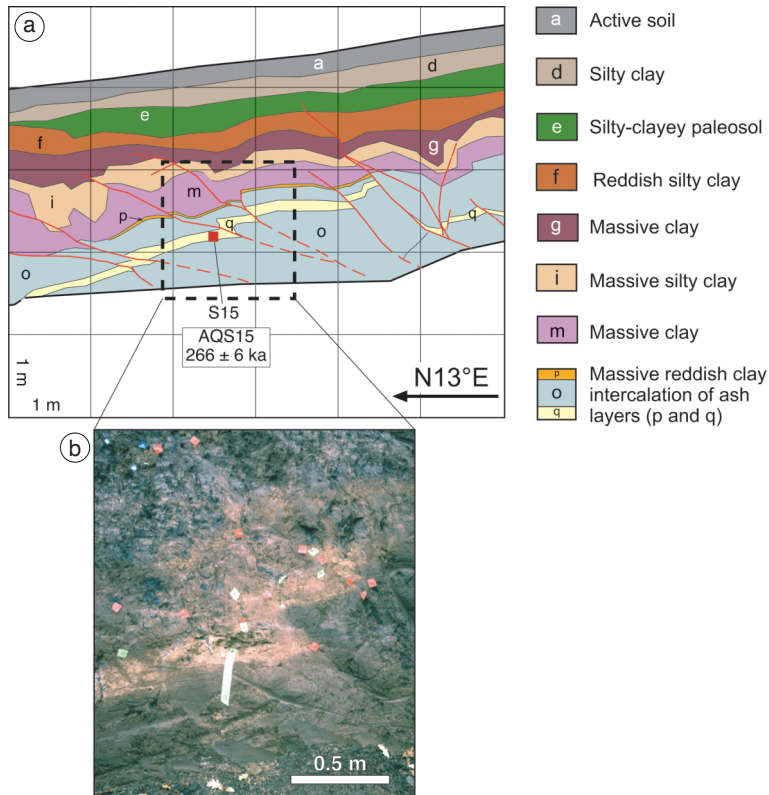
Fig. 4a,b. a) Schematic log of the stratigraphy exposed in a 6 m-long section of the eastern trench wall; and b) photo showing a detail of the volcanic pumice layer studied in this paper. The pumice layer q (the lighter coloured deposit in the photo) is deformed and displaced by secondary reverse and thrust faults, suggesting a local contractional component formed at the toe of a principal normal fault zone.

longs (fig. 4a,b). From the top to the bottom, the trench stratigraphy consists of:

a – fine-grained light brown active soil, with bioturbation and roots approaching the surface. Lower boundary gradually in d;

d – fine-grained reddish-brown silty clay;

e – fine-grained dark brown silty-clayey paleosol;

f – reddish-brown silty clay with light brown laminations and weathered pumice and sparse very fine calcareous-mudstone (bedrock) fragments;

g – massive brown clay with weathered pumice and sparse fine calcareous-mudstone (bedrock) fragments. At the base chips of unit i;

i – massive light reddish-brown clay with fine weathered pumice and sparse minerals;

m – dark reddish-brown vacuolar clay with conchoidal fracture and with diffused manganese concretions mainly at the top of the unit, sparse minerals and very fine sub-angular calcareous mudstone (bedrock) fragments;

o – massive reddish clay with diffused manganese concretions and very fine calcareous mudstone (bedrock) fragments; the unit present intercalation of pumice layers;

p – very thin (up to 3 cm) and localized (>4 m-long) orange-brown ash bed composed by altered pumice; and

q – light yellow pumice layer formed by poorly welded, medium coarse pumice, locally altered, with visible mineral grains. Maximum thickness 10 cm.

Several samples were collected from the stratigraphic sequence to provide time constraints on the depositional and deformational history recorded in the trench, which, on a preliminary analysis, reveals at least three events of surface faulting. In the following, we detail on the geochemical and radiometric characterization of tephra layer q sampled close to the bottom of the trench (fig. 4a,b).

5. Analytical methods

5.1. *Petrochemical analysis*

Major and trace element analysis of pumice from tephra q was carried out using a wave-

Table I. Major oxide (wt%) and trace element (ppm) contents for sample F1, representative of tephra q. Water-free analysis.

Sample	F1
SiO_2	56.89
TiO_2	1.11
Al_2O_3	26.68
Fe_2O_3	8.80
MnO	0.29
MgO	1.78
CaO	1.09
Na_2O	0.15
K_2O	2.91
P_2O_5	0.30
Sum	100.00
Zn	153
Ni	45
Rb	161
Sr	192
Y	43
Zr	679
Nb	82
Sc	9
V	152
Cr	69
Ba	1046
Nb/Y	1.9
Zr/TiO_2	0.10

length-dispersive X-Ray fluorescence spectrometer (Philips PW 1400) at CISAG, University of Naples. Petrochemical composition was obtained on pressed powder pellets and the data were corrected according to procedures described in Melluso *et al.* (1995) (table I). Calibration curves were obtained using 35 international standards. Precision is better than 5% for major elements (excluding P_2O_5) and for Rb, Sr, Y, Zr, Nb, Zn and V, and better than 10% for the remaining trace elements excluding Sc, for which precision is closer to the XRF detection limits.

5.2. $^{40}Ar/^{39}Ar$ dating

$^{40}Ar/^{39}Ar$ age analysis was performed at the Berkeley Geochronology Center using facilities

and procedures similar to those described in Karner and Renne (1998). A sample of tephra *q* was wet-sieved, and then the residue was dried. Nearly, all the residue consisted of equidimensional, optically transparent sanidine, with no evidence of reworking. Sanidine phenocrysts, approximately 1 mm in diameter, have been hand picked from the residue. Twenty crystals were selected for clarity under the binocular microscope and cleaned in an ultrasonic bath of 7% HF solution for approximately one minute to remove surface alteration and to reduce atmospheric contamination. The crystals were placed in an aluminum disk along with the neutron fluence monitor (standard) Alder Creek Tuff sanidine (1.194 Ma; Renne *et al*., 1998) and irradiated at the TRIGA reactor at Oregon State University for approximately 30 min. The irradiation was cadmium shielded to minimize the $^{40}K(n, p)^{40}Ar$ reaction by reducing the thermal neutron fluence (Tetley *et al*., 1980).

A fully automated microextraction-mass spectrometer system was used for the $^{40}Ar/^{39}Ar$ analysis. MAP1 includes a CO_2 laser for sample heating, and a Mass Analyzer Products (MAP) 215 90° sector extended-geometry mass spectrometer. Because there are relatively small crystals associated with this distal ash-fall horizon, it was necessary to analyze multiple crystals at once to increase the Ar signal to significantly above background level. Three or four crystals were placed into each of six pits in a copper disk, and then placed into the microextraction system. Fusion of each pit has been separately done, the released gases scrubbed of reactive species using C-50 getters and a cryogenic condensation trap. The released gases were exposed to the getters for a period of 180 s. Mass discrimination (1.0060± ±0.0022/amu, applied as a power law correction) was monitored by analyzing air pipettes throughout the experiment. Background corrections made from full system blanks were run between every three sample analyses.

6. Results

6.1. *Chemical classification of tephra* q

The major element composition clearly indicates a pervasive alteration of tephra *q* as suggested, for instance, by the high content of Al_2O_3 (23.4%), the very low content of Na_2O (0.15%), and K_2O (2.91%) (table I). To better classify the analysed sample, elements such as Zr, Ti, Nb and Y were used, because of their rel-
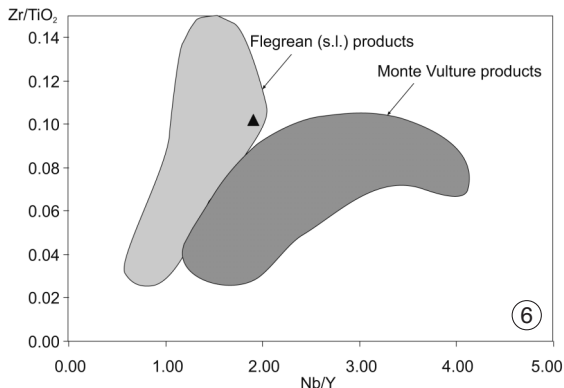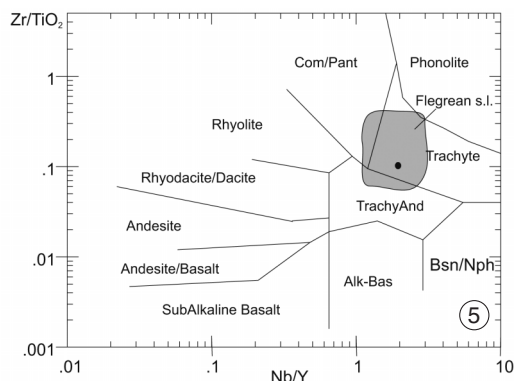
Fig. 5. Classification of sample *F*1 (black dot), representative of tephra *q*, according to Winchester and Floyd (1977). Composition of flegrean products is also shown for comparison (data from Pappalardo *et al.*, 2002).

Fig. 6. Diagram Nb/Y *versus* Zr/TiO_2 showing the geochemical affinity of sample *F*1 (black triangle) with the Flegrean products. Data from Pappalardo *et al.* (2002) for the Flegrean products and from Beccaluva *et al.* (2002) for the Monte Vulture products.

atively immobile behavior during processes of argillization. As a result, tephra *q* plots within the field of trachytic volcanics (figs. 5 and 6) and is quite in agreement with the average composition of Flegrei (s.l.) products (figs. 5 and 6).

6.2. Ar/Ar age of tephra

The multiple-crystal total-fusion ages are presented for each of the six separate pits that contained sanidine from tephra *q* (table II). Ages are reported with ±1σ analytical precision. The ages for all the samples, except sample 33161-03, are statistically indistinguishable at around 260 ka. Sample 33161-03 contained three nearly equidimensional crystals, the total fusion age of which is 366.8±7.6 ka, nearly 100 kyr older than the other five multiple-crystal total-fusion ages. This older age for 33161-03 is probably the result of one xenocryst grain being mixed with two crystals, whose ages are consistent with those crystals from the other sample pits. This suggests an approximate age of ~500-600 ka for the xenocryst, but we caution that this is a gross estimate based on the assumption that each of the three crystals in this pit yielded a similar amount of Ar gas. This assumption may not have been true. Regardless of the age of the xenocryst, sample 33161-03 was eliminated

from our estimate of the eruption age of the studied ash horizon. In order to estimate the eruption age of this pumice layer, we have calculated the error-weighted mean ^{40}Ar/^{39}Ar ratio from the five other samples (see Renne *et al.*, 1996). Based on this error-weighted mean ^{40}Ar/^{39}Ar ratio (see table II), we estimate the eruption age for the Val D'Agri pumice layer to be 266.1 (±4.9) ka (±1σ). We note that the homogeneity of the Val D'Agri pumice, with probably 19 of the 20 sanidine crystals analyzed being the same age, indicates that this volcanic horizon is probably a primary (not reworked) ash horizon. Thus, its position within the Val D'Agri sedimentary succession might be considered a reliable chronostratigraphic marker.

7. Discussion and conclusions

A paleoseismological trench dug on a fault scarp with the intent to investigate the past seismogenic activity of the MMFS exposed a Late Pleistocene-Holocene colluvial succession which includes two distinct tephra layers namely *p* and *q* (fig. 4a,b). In particular, the 10 cm thick tephra *q* is represented by pumice which was petrochemically analysed in terms of major and trace element content, and yielded sanidine crystals suitable for ^{40}Ar/^{39}Ar dating.

Table II. ^{40}Ar/^{39}Ar dating for the studied pumice layer.

Lab. No.	Sample ID	# of crystals	^{40}Ar moles ×10^{-15}	^{36}Ar/^{39}Ar	^{37}Ar/^{39}Ar	^{38}Ar/^{39}Ar	^{40}Ar/^{39}Ar	%^{40}Ar*	^{40}Ar*/^{39}Ar	σ^{40}Aρ*^{39}Aρ	Age (ka)	±1σ
33161-01	AQE-S15	4	9.94	0.01147	0.04912	0.01433	4.51801	25	1.12732	0.04876	280.2	12.1
33161-02	AQE-S15	4	10.79	0.01241	0.04483	0.01397	4.71485	22	1.04533	0.04847	259.9	12.1
33161-03	*AQE-S15*	*3*	*7.09*	*0.00454*	*0.04164*	*0.01311*	*2.81601*	*52*	*1.47543*	*0.03038*	*366.8*	*7.6*
33161-04	AQE-S15	3	5.63	0.00535	0.04600	0.01338	2.64630	40	1.06529	0.02918	264.8	7.3
33161-05	AQE-S15	3	11.21	0.01091	0.03823	0.01444	4.32528	25	1.09902	0.04669	273.2	11.6
33161-06	AQE-S15	3	11.20	0.01405	0.04268	0.01483	5.16950	20	1.01402	0.05316	252.1	13.2
							Weighted mean (5)		1.07056	0.01879	266.1	4.9

Notes: BGC Irradiation 262DK-B; J = 1.3780 (±0.0025)×10^{-4}; Mass Discrimination = 1.0060±0.0022. Sample in italics yielded an age that was not statistically consistent with the remaining samples, and is not included in the error-weighted mean calculation. MSWD = Mean Square Weighted Deviation.

Tephra *q* is characterized by a trachytic composition and the ${}^{40}Ar/{}^{39}Ar$ dating provides an age of 266 ka for this layer.

These results and the present knowledge on the volcanic history of Southern Italy do not allow a definitive identification of the source area for the studied pumice level. In the adjacent Vallo di Diano (fig. 3a), where a sequence of tephra layers have recently been studied, the recorded eruptive period spans the approximate time interval 630-550 ka (Karner *et al.*, 1999), preventing a possible correlation with the HAV succession. However, several considerations can be made:

a) The geochemical features and age of tephra *q*, exclude a correlation with Mt. Vulture (fig. 6), that represents the nearest volcanic area to the HAV trench site. This vent erupted trachytic products only at the beginning of its activity (740 ka; Laurenzi *et al.*, 1993) and the chronostratigraphic reconstruction of volcanic events is not in agreement with the age of 266 ka for tephra *q*: no activity is reported, in fact, in the time-span ranging from 500 ka to 132 ka.

b) The Roccamonfina volcano was highly active between 317 and 230 ka during which the White Trachytic Tuff (WTT) was erupted. However, the correlation of tephra *q* with this event appears to be difficult because the thickness (10 cm) and size (medium-coarse) of the studied pumice are not consistent with the small volume and the minor plinian fall-out of WTT members outcropping at about 200 km of distance from Val D'Agri trench site.

c) On the basis of geochemical affinities, tephra *q* seems to be a typical product of the Campanian Volcanic Zone (Flegrei s.l.) (figs. 5 and 6; table I) whose products have been found up to 900 km to the south. The Campi Flegrei-Procida Island, Ischia and Somma-Vesuvius activities are too recent to be genetically linked to tephra *q*. A proposal might be advanced on the basis of ancient trachytes ignimbrite deposits related to the Campanian Volcanic Zone dated by ${}^{40}Ar/{}^{39}Ar$ method at 205 ka, 184 ka and 157 ka, (De Vivo *et al.*, 2001) and 290 to 246 ka (Rolandi *et al.*, 2003). These data give evidence of an older and previously unknown explosive activity in the Campanian region, which consequently extends the volcanic history of this region by over 200 ka.

In the latter case, similar coeval products are expected to cover a wide area and the occurrence of the tephra *q*, interbedded within the HAV succession, may represent important information for chronostratigraphic reconstruction of volcanic activity in Southern Italy during the Pleistocene.

Acknowledgements

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