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FINDING DISTAL VESUVIUS TEPHRA AT THE BORDERS OF LAGO GRANDE DI MONTICCHIO, IN AF SHALLOW CORING SYSTEM MICRO-CORES

Abstract - This work approaches the study of distal tephra by means of a new micro-coring methodology, and through the correlation between micro-cores and outcropping sections situated at varying distance from the source area. The AF SHALLOW CORING SYSTEM we adopted in the present work is a drilling system that allows the extractions of 10 m long continuous and undisturbed micro-cores. Cores from Visciano (17 km ENE from Vesuvius) and Piano del Dragone (~43 km ESE from Vesuvius) have been compared with the finding in Lago Grande di Monticchio. At a depth of ~1 m all around the palustrine borders of the Lago Grande di Monticchio, we found a tephra we attributed to the Avellino Vesuvian eruption. Compared with our finding, the attribution to the same Avellino eruption of the tephra found between 3 and 3.5 m in the middle of the lake by previous Authors confirms the slower sedimentation rate on the border of the lacustrine basin.

Key words - Micro-coring, distal tephra, tephrostratigraphy, Vesuvius, Monticchio Lakes.

Riassunto - *Ritrovamento di tephra distali del Vesuvio in microcarote AF SHALLOW CORING SYSTEM prelevate al margine del Lago Grande di Monticchio*. Questo lavoro tratta lo studio dei tephra distali per mezzo di una nuova tecnica di microcarotaggio ed attraverso la correlazione di microcarote e affioramenti in sezione situati a distanza variabile dalla sorgente. L'AF SHALLOW CORING SYSTEM adottato in questa ricerca è un sistema di perforazione che consente l'estrazione di microcarote indisturbate lunghe fino a 10 m. Carote da Visciano (17 km ENE dal Vesuvio) e Piano del Dragone (~43 km ESE dal Vesuvio) sono state confrontate con i ritrovamenti del Lago Grande di Monticchio. Tutto attorno alla fascia palustre del Lago Grande di Monticchio, alla profondità di ~1 m, sono stati rinvenuti tephra attribuibili all'eruzione di Avellino del Vesuvio. Confrontata con i risultati di questo lavoro, l'attribuzione alla medesima eruzione di Avellino dei tephra rinvenuti da altri Autori tra 3 e 3.5 m al centro del lago conferma il minor tasso di sedimentazione ai margini del bacino lacustre.

Parole chiave - Microcarotatore, tefra distali, tefrostratigrafia, Vesuvio, Laghi di Monticchio.

Introduction

The study of distal tephra is of particular relevance for physical volcanology and risk assessment related to the dispersal of ash covers from explosive eruptions. One of the major difficulties in studying distal tephra is connected with the finding of a significant number of sections including very distal deposits of reliable stratigraphical attribution. Actually, primary tephra few cm thick are difficult to find in sub-aerial stratigraphical sections because these thin blankets of ashes and crystals are preserved only under particularly favourable sedimentation conditions. For the distal deposits of the active volcanoes of southern Italy, these conditions are typically represented by little quaternary lacustrine basins in the Apennine chain.

Among such lacustrine basins, the Monticchio Lakes area turned out to be the ideal place for finding distal Vesuvius tephra, as it is situated at ~90 km to the east of Vesuvius, along the prevailing direction of wind coming from the Campanian volcanoes (namely Vesuvio, Ischia, Campi Flegrei) (Fig. 1). The Monticchio Lakes occupy two maar craters resulting from the last eruption of Monte Vulture volcano (Stoppa & Principe, 1997), which dates at 132 ± 12 ky BP (Brocchini, 1993). Therefore, all the products of the eruptions which occurred in the Campanian area after this date may have eventually been included in the lacustrine sequences of the Monticchio Lakes. Both Lago Piccolo and Lago Grande have limited surface area, 500 x 350 m and 850 x 600 m, respectively, with maximum depth of 38 and 36 m, respectively. Both lakes are characterised by a low sedimentation rate due to the morphological configuration of the Monte Vulture area (La Volpe & Principe, 1999).

For these peculiarities, during the last decade, the bottom of the Lago Grande di Monticchio (Fig. 2) has been repeatedly drilled to depths of some tens of meters and the cores obtained have been analysed for different purposes (Watts, 1985; Watts *et al.*, 1996, 1996a, 2000; Zolitschka & Negendank, 1993, 1996; Newton & Dugmore, 1993; Robinson *et al.*, 1993; Narcisi, 1996; Hajdas *et al.*, 1998; Narcisi & Vezzoli, 1999; Huntley *et al.*, 1999; Brandt *et al.*, 1999; Brauer *et al.*, 2000; Wulf *et al.*, 2004). In all this literature, the attribution of each tephra layer to a precise eruption of one of the Campanian volcanoes has been performed on the basis of glass chemistry and mineral assemblages and on a more or less consistent tephra age succession. All the cores obtained so far from the Lago Grande, however, are more or less disturbed by both presence of remobilised material and duplication of the stratigraphical sequence, which are caused by the coring techniques used. To solve these problems, in the last few years, we implemented and tested a new micro-coring methodology, which allows one to obtain continuous and undis-

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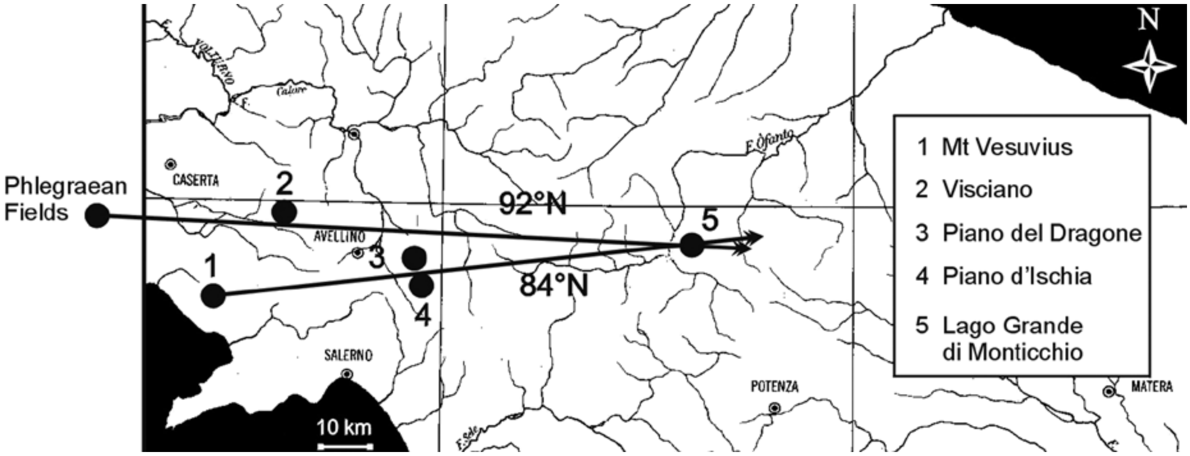

Fig. 1 - Locations of the drilled cores. 84° N and 92° N are the orientations of two imaginary strips connecting the Monticchio Lakes with Vesuvius and Phlegraean Fields, respectively.

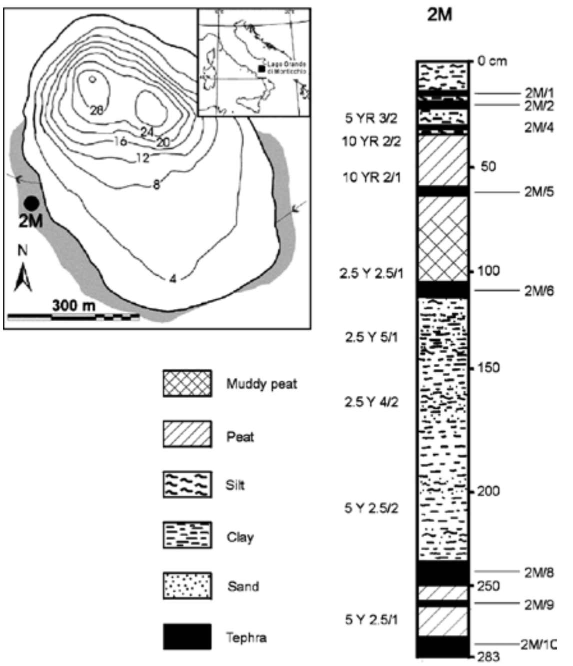

Fig. 2 - Map of the Lago Grande di Monticchio showing the location of core 2M. The micro-stratigraphy of this core is also shown. The Munsell soil colours are indicated on the left of the column, whereas the tephra sampled for analyses are indicated on its right.

turbed cores, albeit only a few meters long (Principe *et al.*, 2003).

The purpose of this work is:

1. to illustrate the power of our micro-coring methodology;
2. to set out a new approach to the study of distal tephra, through the correlation between micro-cores and outcropping sections situated at varying distance from the source area.

Coring methodology

The AF SHALLOW CORING SYSTEM is a continuous-core drilling system for granular and cohesive rocks, specifically engineered for quick coring, which has been successfully applied to obtain continuous cores for detailed stratigraphic studies (Principe, 1998). The use of a specially designed and engineered textile liner allows 100% recovery of the drilled sequence, with nil to negligible alteration of geotechnical parameters (Pl. 8a) down to a depth of 10 m. As far as we know, this coring system is at present the only coring system allowing 100% sample retrieval, even in saturated loose sands, as is the case with some parts of the Monticchio Lakes sediments.

The AF SHALLOW CORING SYSTEM is composed by a drilling string, ultra-light drilling pipes, coring bit, core head, sheath cartridges, a pneumatic hammer and a recovery jack (Principe *et al.*, 2002).

The relatively small attainable depth (max 10 m) represents the major limit of the AF SYSTEM methodology and it may either restrict the age interval of investigation or direct drilling to condensed sequences, if possible. Nevertheless, we stress the fact that deeper cores obtained by all the other methods (for instance the Livingston piston corer) are discontinuous, since only 50-100 cm of sediments are extracted in each coring operation. Therefore, the cores obtained are the sums of these short segments and are severely affected by both presence of remobilised material and duplication of the stratigraphical sequence, due to the absence of a liner protecting the open hole.

Because of the relatively limited length of the core obtainable by means of the AF SYSTEM, the choice of the sampling site is critical and places with the lowest possible sedimentation rate have to be privileged. In the case under study, we first focused our attention to test whether the palustrine environment all around the border of the Lago Grande di Monticchio preserves the same tephra layers as the deeper portions of the lake. Due to the smaller amounts of clay and organic sedi-

ments accumulating in this palustrine environment with respect to the lacustrine basin, the former represents an obvious choice for the application of our methodology. In this first field work step, therefore, the stratigraphies of the deeper cores available in the literature have been compared with the stratigraphy reconstructed by regularly spaced shallow drillings all around the borders of the two Monticchio lakes (Malfatti, 1996; Principe *et al.*, 1997). These detailed shallow drillings have been performed also in order to avoid possible stratigraphical hiatus due to local sedimentation conditions along the border of the lakes.
Then, on the basis of the stratigraphical correlations between all the obtained cores, a single place has been selected and drilled to sample the tephra layers to be submitted to different types of analysis. The micro-stratigraphy of this selected core (called 2M) is reported in Figure 2, with the indication of the sampled tephra. The core is dominated by repeated sedimentation of peat and silt (Pl. 8a-A, 8a-B, 8a-C, and 8a-D), indicating recurrent changes from palustrine to lacustrine sedimentation, with a number of tephra layers interposed at various levels in the sequence. Ashes, mm-size pumice fragments, and free crystals are well evident in the tephra layers of core 2M (Pl. 8a-B, 8a-C, 8a-D, and 8a-E). As expected, these characteristics contrast with those of a tephra found in the dried up lacustrine basin of Piano del Dragone (~40 km to the east of Vesuvius, half the distance from the volcano compared with the Lago Grande; Fig. 1), which shows a sensible increase in both the component-size and tephra thickness (Pl. 8a-F). On the other hand, even if the tephra attribution is easier, due to the relatively larger pumice dimension, the accessible stratigraphical record at Piano del Dragone is shorter than at Lago Grande, because of the notable depth of cultivated soils and the proximity to the volcanic centres that make single tephra layers thicker.

Sampling of tephra layers

The lacustrine and palustrine sedimentation determines mingling of tephra with organic materials, clays, and other non-volcanic materials. All these non-volcanic materials have been separated in the laboratory from the tephra fragments by means of repeated washing. Core segments containing tephra layers have been cut from the core at 1-2 mm distance from the non volcanic-volcanic contact. These samples have been dried under a UV lamp (at a temperature of ~70°) and then disaggregated and washed in a china cup with deionised water for removing the finest fraction. Then, with the help of a 35 μm-wide net and repeated immersion of the sample in an ultrasonic bath for few minutes, the fine, diatomite-rich fraction has been removed. Samples have been washed, dried and weighed after each passage.
Resulting material has been separated in the granulometrical classes > 250, > 150, > 106, > 40, and > 35 μm by means of micro-sieves. The amounts (in mg) of each class are given in Table 1 and histograms of Figure 3. The thinnest (2M/4, 0.5 cm thick) tephra layer contains the biggest amount of fine non-volcanic material (35%) while the thickest (2M/6C, 12-13 cm thick) tephra layer contains the smallest mass of external material (4%). This fact highlights both:

– the difficulty in sampling very thin tephra layers without cutting from the core little portions of the non volcanic materials present at its top and bottom;
– the percolation of fine clays into the open structure of the volcanic grains, which is effective only in the first millimetres of the deposit.

The unimodal pattern, typical of the fallout deposits, is evident into the histograms of Figure 3, together with a peak of fine ashes. This big amount of fine glass fragments is interpretable as one of the effects of the long travelling distance from the eruptive vent.

Tab. 1 - Granulometrical analyses (in mg). Five granulometrical classes (from > 250 to > 35 μm) have been separated by means of micro-sieves.

Layer	> 250	> 150	> 106	> 40	> 35	< 35	Non volcanic	Total	% Non volcanic
2M/1	-	0.23	0.26	1.22	0.29	1.51	1.37	4.9	28
2M/2	-	0.16	0.39	1.48	-	3.01	1.01	6.32	16
2M/4	-	0.21	0.25	0.01	0.47	0.09	0.56	1.59	35
2M/5	-	0.46	0.47	2.35	0.28	4.58	1.19	9.34	13
2M/6A	0.48	0.78	0.81	0.69	0.11	4.04	0.85	7.77	11
2M/6B	2.28	1.45	0.99	0.23	0.02	0.49	0.26	5.72	5
2M/6C	6.71	2.74	0.52	0.38	0.03	1.23	0.52	12.13	4
2M/8	1.98	1.06	0.48	0.99	0.15	2.86	1.32	8.84	15
2M/9	-	0.10	0.20	1.26	0.37	3.45	0.98	6.36	15
2M/10	0.51	0.17	0.45	0.60	0.05	1.66	1.53	4.97	31

«Non volcanic» refers to the fine organic material that has been removed from the sample by means of the purification procedures.

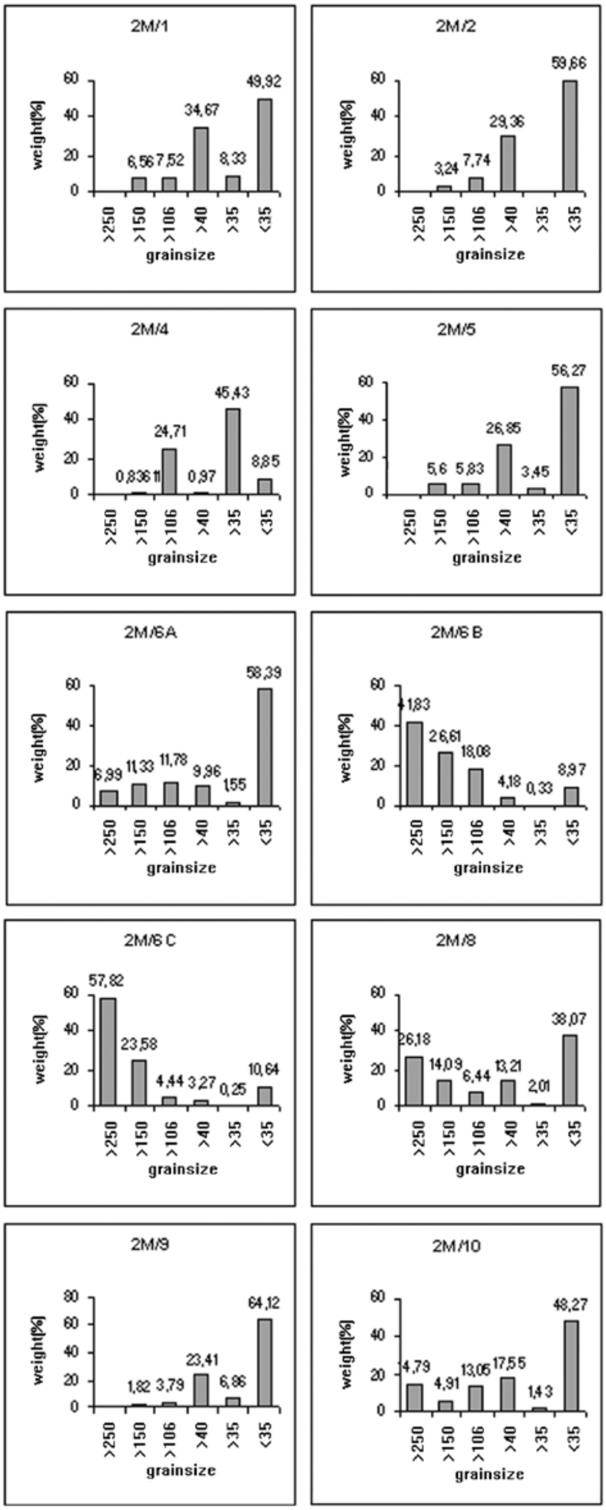

Fig. 3 - Histograms showing the granulometric distribution of the sampled tephra. Gain-size is measured in µm. Numbers at the column top refer to the weight % value for each granulometric class, calculated free from non-volcanic materials.

The presence of the granulometric class > 250 µm suggests that samples 2M/6, 2M/8 and 2M/10 are representative of either the most energetic pumiceous fallout or those with the dispersion axis closest to the vent-Laghi di Monticchio alignment (92-84° N, Fig. 1).

ANALYTICAL PROCEDURES

Petrography

Thin sections have been obtained from consolidated samples, prepared by immersion into epoxy resin. Thin sections of the four main granulometric fractions (> 250, > 150, > 106, > 40 µm) of all the 10 sampled tephra have been studied petrographically.

The abundances of the different components of each tephra layer are reported in Table 2. Glass is the main component and it is especially abundant in the > 250 and > 150 µm granulometric classes. Fresh and well vesiculated lightly coloured to colourless fragments are generally present. The vesicle shape varies from spherical to ovoid, in sub-rounded clasts (pm); elongated, tube-like forms (tb), sometimes coalescent and plastically deformed, and brown blocky fragments (sv) are also recognised. Bubble fragments with the classical X and Y morphology and scoria fragments are present in minor amount. Lithic fragments are represented by more or less fresh lavas, with subordinated tuffs and limestones. Free crystals and crystal fragments are present in all the samples studied, and turned out to be especially abundant in the > 106 µm granulometric class. Tephra 2M/6 clearly shows crystal enrichment from top to bottom. The main crystalline phases are dark mica, clinopyroxenes and feldspars. A number of other phases are present in very low amounts (2 or 3 crystals or crystal fragments for each thin section). The mineral assemblages shown in Table 2 are consistent with tephra provenance from the Campanian volcanoes and specifically from the Vesuvius and perhaps the Phlegraean Fields, also based on the known eruption ages. It is beyond the aims of the present study to investigate crystal settling inside the eruptive clouds, but the relative abundance of mica with respect to leucite crystals suggests that settling phenomena inside the volcanic cloud, at this distance from the vent, are able to affect the deposition process, as already pointed out by Juvignè (1992). Therefore, the leucite-bearing layers can be attributed to Vesuvian explosive eruptions, whereas the absence of leucite, without other indications, does not indicate the provenance from the Phlegraean Fields as it might simply result from leucite settling in the eruptive cloud.

Physical analyses

An immersion test has been performed in order to elucidate the dynamics of pumice and crystal settling into the shallow waters of the Monticchio Lakes. Some mg of each sample have been immersed in a 1,000-ml glass beaker full of deionised water and their settling behaviour has been observed at different time intervals. Qualitative results are shown in Figure 4. In few minutes all the tephra material reached the bottom of the glass beaker, since pumices with density > 1 do

Tab. 2 - Physical properties and mineralogy (volume % and relative abundances of various mineral phases) of the analysed tephra. In the second column is the depth of the base of each tephra layer.

Layer	Bottom (cm)	Thickness (cm)	Colour	Glass (%)	Lithics (%)	Crystals (%)	Additional minerals
2M/1	18	1	2.5Y4/2	60 (pm > sv >> tb)	25	15 (dm ≥ cpx ≥ feld)	Lc, ga
2M/2	24	3	2.5Y4/2	20 (sv >> pm)	15	65 (cpx ≥ feld > dm)	Amph, ga, lc
2M/4	33	0.5	2.5Y4/2	55 (pm > tb > sv)	10	35 (feld >> cpx > dm	Amph
2M/5	63	3	2.5Y5/2	60 (pm > sv)	20	20 (feld ≥ cpx > dm)	Amph, ox, ol, lc, zir
2M/6A	112	7	2.5Y6/1	30 (pm > tb > sv)	35	45 (feld ≥ cpx)	Amph, lc, dm
2M/6B				40 (pm > tb > sv)	30	30 (feld ≥ cpx)	Amph, lc, dm, ga
2M/6C				65 (pm >> sv ≥ tb)	20	15 (feld > cpx)	Amph, dm, ga
2M/8	250	1.5	5Y6/2				
5Y5/4	70 (tb >> sv ≥ pm)	10	20 (feld > cpx)	dm, ox			
2M/9	259	2	2.5Y5/1	70 (pm ≥ tb >> sv)	10	20 (feld >> dm ≥ cpx)	
2M/10	283	9	2.5Y7/2				
5Y4/2	65 (pm > tb > sv)	10	25 (feld > cpx ≥ dm)	Sph, ol			

Lithics are mainly represented by fresh and altered lava fragments. pm: pumices with circular or ovoidal vesicles; sv: blocky shard; tb: tube like pumices; dm: dark mica; cpx: clinopyroxenes; feld: feldspars: Lc: leucite; ga: garnet; Amph: amphibole; ol: olivine; ox: opaque minerals; zir: zircon; Sph: sphene. Additional minerals are present as few crystals or crystal fragments.

not float (Juvignè, 1992). However, some differences have been observed; all components (pumices, scoriae, crystals and lava fragments) reached the beaker bottom together, without any fractionation for the low granulometric classes, between 40 and 106 µm. Conversely, the pumices of the > 150 µm class remained suspended in the water for a longer time interval with respect to other components.

This massive sedimentation for the low granulometries suggests that the crystal-rich, basal layer of the 2M/6 tephra has to be considered as a primary feature of the volcanic cloud rather than attributed to differential settling of tephra components in lake waters.

SEM analyses

Mineral and glass analyses have been performed by means of the Philips EDAX 9900 device and related facilities of the SEM laboratory at the Earth Sciences Department of Perugia University.

Among the mineral phases that are present in the different tephra, glass, feldspars, clinopyroxenes, dark mica, leucite, amphibole and garnet have been analysed. In particular the pyroxenes are salite-diopside, feldspars are shown to be plagioclases of variable composition, and dark mica are shown to be phlogopite. Table 3 shows the chemical composition of glasses.

The glass and mineral analyses are consistent with a Vesuvian-Phlegraean provenance of tephra (see Wulf *et al.*, 2004 for deeper discussion on chemical comparison). It is difficult, by means of this kind of semi-quantitative data, to be more precise in distinguishing between one or another of the well known Vesuvius recent eruptions. The reason for this is the remarkable variability in chemical composition of all the main recent eruptions of Vesuvius (see, for instance, Landi *et al.*, 1999 for the Pomici di Base eruption and Muesschumaker, 1995, for the 79 AD eruption). Such a chemical variability cannot be completely reproduced by a few fragments from a tephra that probably constituted a non-representative selection of the different components of the original deposits, due to the long distance travelled. In a panorama so rich in «trachytic» glass, chemical data allow a precise attribution only in the case of presence of atypical characters, such as for instance the unusually high Na_2O content of the Avellino products, that are recognizable in the glass samples 2M/6A and 2M/6C, and contribute in the attribution of this tephra layer to that eruption.

DATA DISCUSSION

Along an imaginary strip connecting the Monticchio Lakes with the Vesuvius and Campi Flegrei source area (Fig. 1), we considered other coring localities, namely:

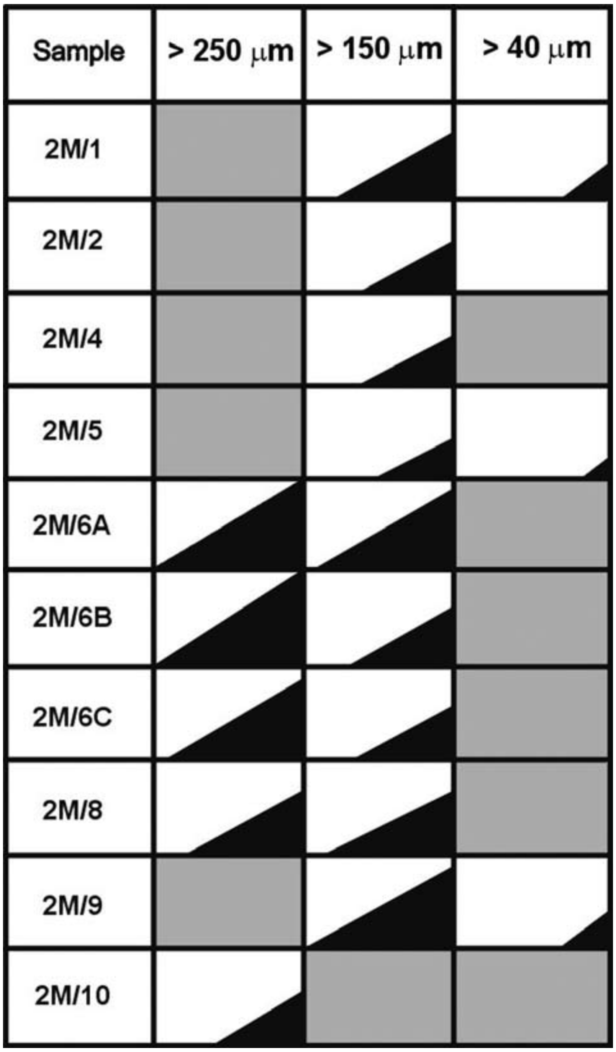

Fig. 4 - Behaviour upon the immersion into deionised water of each sampled tephra layer. The black and white portions of the rectangles correspond to the proportion of the material firstly suspended (black) or that immediately reached the bottom (white). The three main granulometric fractions > 250, > 150, and > 40 µm have been considered. In grey the granulometrical classes that are not represented into the samples.

– the morphological depression of Visciano, 17 km ENE from Vesuvius;
– the two past lacustrine areas of Piana del Dragone and Piano d'Ischia, ESE from Avellino town, at a distance of ~43 km from Vesuvius and finally Lago Grande borders.

Analysing firstly the more proximal of these location we found that some of the most important events of the very recent activity of the Vesuvius and Phlegraean Fields are represented in the Visciano area, in a stratigraphical record that spans the ~37,000 years from today to the Campanian Ignimbrite deposits situated at the bottom of the succession investigated (Principe, 1998).

The stratigraphic columns of Plate 8b show that the deposits of the 1631, 79 AD, Avellino, and Agnano Pomici Principali eruptions are recognizable in this area, above the Campanian Ignimbrite. At this distance from Vesuvius, the depositional characters of each of these eruptions are still perfectly evident, allowing reliable stratigraphical correlations.

Only few reworked pumices attributable to the Vesuvian eruption of 79 AD have been found in the Visciano area. This fact is in agreement with the well known distribution of such a fallout to the SSE from Vesuvius (Sigurdsson *et al.*, 1985). For this reason, the 79 AD pumices are not expected to be found in the distal sections of Piana del Dragone and Lago Grande di Monticchio.

The most recent eruption that is represented in the Visciano area is the 1631 Vesuvian small-scale plinian eruption (Rosi *et al.*, 1993).

The isopachs of 1631 eruption describe a very narrow elongated ellipse with the minor axis of ~1 km and the major dispersal axis with ENE orientation. Deposits clearly referable to the 1631 eruption have been found, with a thickness of 12-13 cm, in the core drilled at Piana del Dragone (Pl. 8a-F) (Rosi *et al.*, 1996; Tab. 4). As a matter of fact, the locations of both Piana del Dragone and Monticchio Lakes coincide with the dispersion axis of such an eruption (Fig. 1 and Tab. 4).

On the contrary, the Avellino fallout deposits of Vesuvius are present in the Visciano area with thickness > 1 m (Pl. 8b). At this medium-to-distal distance from the source, the Avellino sub-aerial fallout deposit preserves all its proximal characters (Arnò *et al.*, 1987; Cioni *et al.*, 1999), namely the presence of a fine-grained crystal-rich basal layer and of two pumice fallout layers. In the upper fallout unit, pumices are grey in colour and lithics are more abundant than in the lower unit. The same characteristics are recognisable in the 2M/6 subaqueous tephra layer sampled at Lago Grande di Monticchio at a depth of ~110 cm (Fig. 1 and Pl. 8a-E).

The Pomici di Base Vesuvius eruption (Bertagnini *et al.*, 1998; Tab. 4) has not been found in the Visciano area, even if the related fallout deposit is testified to be present at places in the nearby area (Zanchetta *et al.*, 2004). The presence of reworked materials of the Pomici di Base eruption in the alluvial fans at the base of the limestone relief in all this area is due to important erosional episodes that evidently prevented the preservation of the primary pyroclastic deposit (Brocchini, 1999; Zanchetta *et al.*, 2004).

Table 4 synthesises the other eruptions from the Vesuvius and Phlegraean Fields that are expected to be found in the few meters of the sedimentation record we sampled. Above the 2M/6-Avellino marker, only the products of five Vesuvian eruptions are expected to be present, namely those occurred in 472 AD, 1631, 1822, 1906, and 1944 (for this last eruption also historical accounts are available). Thepra layers attributed to the first two of these eruptions has been found in the middle-of-the-lake-core studied by Wulf *et al.* (2004). Comparing the previous literature on the Lago Grande di Monticchio cores and the results of our study we found some points of interest, essentially linked to both

Tab. 3 - SEM glass analyses. All analyses (weight %) have been performed by the Philips EDX 515, EDAX 9900, of the Earth Sciences Department of the Perugia University. The mean of the performed analyses is reported for each sample. In parenthesis the Standard Deviation. Zero indicates values under the detection limits.

Sample	N. of analyses	SiO_2	TiO_2	Al_2O_3	FeO	Fe_2O_3 tot	MnO	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5
2M/1	6	56.75 (0.76)	0.43 (0.15)	20.62 (0.36)	3.93 (0.06)	4.37 (0.07)	0.00	0.81 (0.80)	4.87 (0.68)	3.61 (0.67)	8.24 (1.40)	0.75 (0.10)	-
2M/2	3	61.00 (7.51)	0.52 (0.14)	19.45 (1.89)	5.00 (2.79)	5.55 (3.10)	0.00	4.23 (3.45)	2.92 (0.91)	1.19 (1.08)	5.68 (2.03)	0.00	0.00
2M/6A	6	59.43 (0.33)	0.11 (0.12)	21.50 (0.51)	1.99 (0.43)	2.21 (0.48)	0.28 (0.19)	0.28 (0.19)	1.96 (0.28)	6.89 (0.46)	6.92 (0.27)	0.76 (0.10)	-
2M/6C	6	61.08 (0.55)	0.00	22.00 (0.22)	1.83 (0.80)	2.03 (0.89)	-	0.00	2.45 (0.98)	5.07 (1.41)	6.85 (1.05)	0.73 (0.19)	-
2M/8	5	60.15 (2.39)	0.41 (0.37)	19.19 (0.52)	3.83 (0.85)	4.26 (0.95)	0.00	1.18 (0.97)	3.22 (1.11)	2.63 (0.27)	8.87 (0.65)	0.53 (0.22)	-
2M/9	6	63.33 (0.59)	0.28 (0.17)	18.87 (0.38)	2.76 (0.38)	3.06 (0.42)	0.00	0.35 (0.24)	2.35 (0.31)	2.46 (0.76)	8.95 (0.85)	0.64 (0.09)	0.00
2M/10	6	64.50 (0.85)	0.39 (0.21)	18.49 (0.48)	2.53 (0.47)	2.81 (0.52)	0.00	0.22 (0.14)	1.97 (0.42)	3.56 (0.96)	7.54 (0.80)	0.82 (0.19)	0.00

Tab. 4 - The main recent Vesuvian and Phlegraean Field eruptions with a fallout component able to reach the Monticchio Lakes distal area.

Eruption	Vent area	Age	Dispersal axis	Data source
Campanian Ignimbrite (C.I.)	Phleagrean Fields	37.1 ± 0.4 ky	N 110° E	1,2
Codola	Phlegraean Fields	25.1 ± 0.4 ky	-	3, 4
Pomici di Base	Somma-Vesuvius	18-19 ky	N 80°E	5, 6
Agnano Pomici Principali	Phlegraean Fields	0.95-1.1 ky	N 80°E	4, 7
Mercato	Somma-Vesuvius	8.0 ± 0.3 ky	N 70° E	4, 5
Avellino	Somma-Vesuvius	3.8 ± 0.1 ky	N 60° E	4, 5
79 AD (pumice fall)	Somma-Vesuvius	AD 79	N 150° E	5,6
79 AD (ash fall)	Somma-Vesuvius	AD 79	N 90° E	5,6
472 AD	Somma-Vesuvius	AD 472	N 65° E	9
1631 (dark gray scoria fall)	Somma-Vesuvius	1631	N 80° E	10, 11
1631 (light gray scoria fall)	Somma-Vesuvius	1631	N 85° E	10, 11
1822	Somma-Vesuvius	1822	N 145° E	12
1906	Somma-Vesuvius	1906	N 60° E	12
1944	Somma-Vesuvius	1944	N 115° E	12

(1) Deino *et al*., 1994; (2) Rosi *et al*., 1999; (3) Alessio *et al*., 1974; (4) Arnò *et al*., 1987; (5) Andronico *et al*., 1995; (6) Sigurdsson *et al*., 1985; (7) Bertagnini *et al*., 1998; (8) Delibrias *et al*., 1979; (9) Rosi & Santacroce, 1983; (10) Rosi *et al*., 1993; (11) Rosi *et al*., 1996; (12) Arrighi *et al*., 2001.

the depth of occurrence and the attribution of the tephra layers.

Narcisi (1996) attributed the tephra L1, L2, and L3, situated at depth of 315, 319, and 331 cm, respectively, to the subplinian eruptions recognized by Arnò *et al.* (1987) between the Avellino and the 79 AD plinian episodes. Recent studies (Andronico & Cioni, 2002), however, have shown that the fallout deposits of these sub-plinian eruptions have a rather limited dispersal, which makes unlikely their presence at Monticchio. The tephra L4 (662 cm depth) and L5 (787 cm depth) have been assigned by Narcisi (1996) to the Mercato Vesuvius eruption and to the Agnano Pomici Principali, originating in the Phlegrean Fields (Rosi & Sbrana, 1987), respectively.

Ramrath *et al*. (1999) attributed to the Avellino Vesuvius eruption the first tephra they recognized into the sedimentary records of both Lago Grande di Monticchio (between 3 and 4 m depth) and Lago di Mezzano (between 5 and 6 m depth), based on 14C dating and

varve chronology. It must be noted that the Lago di Mezzano is situated at more than 300 km from Vesuvius, in a NNE direction. The attribution of the Lago di Mezzano tephra to the Avellino eruption from Vesuvius, therefore, is at variance with the known ENE-ward distribution of these fallout deposits (Tab. 4).
The general volcanic stratigraphy of our core 2M from Lago Grande di Monticchio includes eight tephra layers. The correlation between these tephra is well traceable all over the perimeter of the two Monticchio Lakes (Malfatti, 1996). The most important tephra marker we found is undoubtedly the 2M/6 layer. All its physical, mineralogical and chemical characters suggest the attribution of this tephra to the Vesuvian Avellino eruption, which is expected to be present in the Monticchio Lakes area based on the known dispersal of the fallout deposits of this eruption (Tab. 4).
The attribution to the Avellino eruption of the tephra found at 315 cm in the middle of Lago Grande di Monticchio by Ramrath *et al.* (1999) is reliable and, compared with our finding of the same tephra (2M/6) at 110 cm depth on the lake borders, confirms our assumption that the sedimentation rate on the borders of this lacustrine basin is lower than in the basin itself, where Ramrath *et al.* (1999) obtained their core.
Further interesting findings of previous studies are tephra L9 from Narcisi (1996) (corresponding to tephra C33 by Newton & Dugmore, 1993), situated at a depth of ~11 m and pertaining to the Vesuvian Pomici di Base, and the tephra layer C41 of Newton & Dugmore (1993), placed at a depth of ~14.5 m, and representing the Campanian Ignimbrite deposit. More recently, Wulf *et al.* (2004) found, and attributed on the base of varve counting, the CI coigmimbritic ash layer (TM-18) at a depth of 25 m into Lago Grande di Monticchio. These layers might be found along the borders of the Monticchio lakes as well, at depth attainable by AF SHALLOW CORING SYSTEM. We hope to be able to confirm this expectation by means of further investigations.

CONCLUSIONS

In the study of the very recent tephra present in the Monticchio lakes area, the major limitation of the applied coring methodology, that is the limited length of the obtainable cores, has been minimised by a careful selection of the drilling sites. Drilling on the palustrine border of the small lacustrine basin of Lago Grande by the AF SHALLOW CORING SYSTEM has allowed us to reach the same tephra layers at a much smaller depth than in the middle of the lacustrine basin. For instance, the Avellino tephra layer has been repeatedly found by us at a depth of ~1.1 m, which is substantially smaller than the depth of 3.15 m, where the same level was found in the lake basin by Ramrath *et al.* (1999). Indeed the AF SHALLOW CORING SYSTEM allows one to obtain 10 m of a truly continuous, undisturbed core instead of thirty 1 m long segments that can be affected by presence of remobilised materials in the obtained core and duplication of the stratigraphical succession. In addition, the AF SHALLOW CORING SYSTEM is operated by 1 or 2 persons with a small car, whereas other classical drilling techniques require a drilling rig operated by 3 or 5 persons and the use of at least two large vehicles or a truck for moving operations.
Chemical data are of great importance in understanding the provenance of a tephra layer from a given volcanic district rather than from another, and to attribute tephra layers to very well known eruptions of a given volcano. However, in the volcanological literature, a complete set of analyses of all depositional units of all the explosive eruptions of interest is not yet available, not even for all the major eruptions. In addition to this fact, distal tephra may be not fully representative of the erupted products due to fractionation processes occurring in the eruptive cloud and, possibly, even during the deposition in an aqueous environment. Actually, with increasing distance from the source, the components present and perhaps the tephra chemistry change.
In conclusion the attribution of an isolated tephra layer to a given eruption only on the basis of the chemistry of glass and mineral fragments have to be considered as not completely reliable.
Measurement of physical parameters of distal tephra deposits, such as the granulometry and components, can provide further data that have to be fitted into the overall framework of a given explosive eruption (dispersal axis, mineral and lithic assemblage, chemistry etc.) for making comparative studies more reliable, assumed that the physical and chemical characters of all the explosive eruptions of interest are very well known.
For these reasons we prefer an approach to the distal tephra attribution based on the stratigraphical background and the stratigraphic continuity with increasing distance from the volcanic source. This stratigraphical continuity can be established by means of a series of stratigraphical sections and cores at variable distance from the source area, along the dispersal axis of well known eruptions, assumed as stratigraphical markers.

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