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The Agro Pontino region, refuge after the Early Bronze Age Avellino eruption of Mount Vesuvius, Italy?

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In recent years it was discovered that the Middle to Late Holocene infill of the Agro Pontino graben (Central Italy) held a tephra layer originating from the Avellino eruption of the Vesuvius volcano. The eruption is dated to 1995 ± 10 calBC and took therefore place during the Early Bronze Age. This was a violent eruption, covering large parts of Campania, the region in which the volcano is situated, with its ashes. The local population had time to flee, but did not return for a period of hundreds of years. One of the possibilities is that people fled to the quiet Agro Pontino, at a distance of 120 km, to settle.

The fact that the low-lying parts of the graben hold wet, organic deposits of the appropriate age, containing the Avellino tephra layer, provided an opportunity to assess whether an influx of new inhabitants is discernable directly after the Avellino event, as a substantial number of newcomers might be detected by an intensification of anthropogenous stress on the environment. The question is tackled by means of pollen analysis, plant macro-remains, malacology and a small excavation.

The outcome of these investigations shows that some impact on the environment is visible, but that it is far from clear whether this effect is due to people from abroad or due to an increase of the local population.

1 Introduction

In recent years, the Agro Pontino graben (Southern Lazio, Central Italy) was shown to hold an important Middle to Late Holocene geo-archive, which offers major possibilities for retrieving detailed information on the history of the vegetation and human occupation over that period (*e.g.* Van Joolen 2003; Eisner and Kamermans 2004; Sevink *et al*. 2011; Feiken *et al*. 2012). Crucial for our present research was the discovery by Sevink *et al*. (2011) that sediments in the low-lying central part of the Pontine plain hold the Early Bronze Age Avellino pumice layer (AV layer) originating from an eruption of the Monte Somma/Vesuvius volcano and dated with great precision to 1995 ± 10 calBC (fig. 1). This eruption was much heavier than the well-known eruption that covered Pompeii with its ashes.

The AV layer is intercalated in a lacustrine sequence, deposited in a shallow lake (fig. 2). To the northwest this lake graded into a river delta and further upstream into a riverine plain with levees (Sevink *et al*. 2013; Feiken 2014). The lake came into full existence around 2000 calBC and its border zone is known to hold Bronze Age archaeological sites, such as Tratturo Caniò (Feiken *et al*. 2012) and Campo Inferiore (Sevink *et al*. 2011). Peaty deposits at its edges reveal traces of repeated burning of the local carr, interpreted as anthropogenous. Later on, during the Iron Age and subsequent Roman Period, the lake gradually shrank to a poorly drained, prevalently marshy area in the northeast of the graben, a situation that more or less persisted until the reclamation of the area in the 20th century (Feiken 2014).

The study presented here was triggered by publications on the impact of the Avellino eruption on Early and Middle Bronze Age human population in Campania (southern Italy), especially the 2013 publication by Di Lorenzo *et al*.. To cite them: "The Pomici di Avellino eruption had a very strong impact on a large area, striking both the Campanian Plain and the surrounding Apennine Mountains… A careful reappraisal of the reports regarding the Early and Middle Bronze Age sites, evidenced a protracted period of depopulation of the area affected by the by-products of the eruption… A complete reoccupation of the area occurred at the end of the Middle Bronze Age, about five centuries after the eruption."

The population is not reported to have perished. People must have fled to other areas, to resettle there and remain there for a long period. Where could they have fled to? Northwards, as far as the Agro Pontino, about 120 km away? The Agro Pontino is reported to have been not very densely populated at that time (Kamermans 1993; Van Joolen 2003; Alessandri 2009) and may have provided a refuge. If so, a substantial influx of newcomers, essentially farmers, should have had an impact on its vegetation.

The various Holocene deposits were studied in the past more than once, but recent research has led to the conclusion that their radiocarbon datings are not reliable (Sevink *et al*. 2013) and that earlier hypotheses on the vegetation and prehistoric land use of the Agro Pontino were fraught with errors due to the poor time frame (Van Joolen 2003; Eisner and Kamermans 2004). This prompted the palaeoecological study of new sections. Moreover, the well-dated AV-layer had not been noticed in earlier studies, and looking for it in

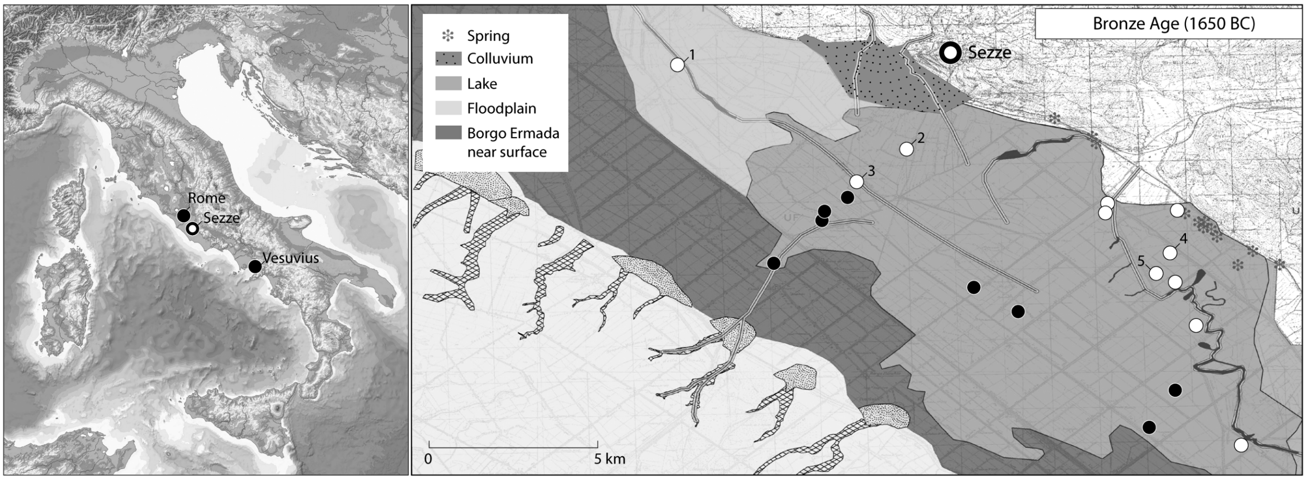

Figure 1a and b. The situation of the Agro Pontino and Mount Vesuvius (a); the lake (situation 1650 BC) with indication of the places mentioned in the text (b). Paleogeography after Feiken 2014. White dots: AV ash in lacustrine deposits, black dots: AV ash in black clays/marsh. Tratturo Caniò 1, Campo Inferiore 2, Ricci 3, Mezzaluna3 4, Mezzaluna cored by Eisner and Kamermans 5

Figure 2. The section Mezzaluna 3 with the layer of AV ash embedded in the whitish lake marl. Photo J. Sevink

suitable new sections was also an important aim of the recent work.

In this paper, results are reported for two new sites in the Agro Pontino graben holding the AV-layer: Ricci and Mezzaluna.

2 Material and methods

2.1 *general*

The distribution of the AV ash in the central and southern extension of the lake and the characteristics of the sedimentary sequences in which this layer occurs was checked by systematic coring, using as background the distribution of Holocene peats and of clays that form part of the Terracina complex (Holocene marine/lagoonal deposits) as indicated on the soil map by Sevink *et al.* (1984). Observations were made through coring by hand (to about 5 m depth) and by observations in all pits and trenches that were found during regular visits to the area over the past years. Relevant sections were described and sampled for palaeoecological study and identification of volcanic ash layers. Two main facies types can be distinguished: a) calcareous and more or less peaty lacustrine deposits formed under aerobic conditions in open water, and b) pyritic black clays formed under anaerobic marshy conditions. The latter type of deposits prevail in the south-western extension of the lake, where the Holocene deposits are generally thin (less than 1 m mostly) and rest on Pleistocene clays of the Borgo Ermada complex (see Sevink *et al.* 1984). The AV-layer is the only distinct ash layer encountered in the Holocene deposits. It is a nearly continuous layer about 1-2 cm thick, which invariably has a rather light yellow to grey colour and contains macroscopically identifiable millimetre-size dark biotite and sanidine crystals. A full description of its composition is given in Sevink *et al.* (2011).

This work led to the selection of two sections for a more detailed study: a section in a very large and deep temporary pit, dug for the construction of an irrigation water reservoir and called Ricci after the owner of the land, and a new section in the area where previously important palynological work had been carried out, *e.g.* Mezzaluna (Eisner and Kamermans 2004). This new section is called Mezzaluna 3. The identification of ash layers encountered as the AV-layer was based on the known tephrochronology of Central Italy and on the habitus and mineralogical composition of the tephra. The vegetation before and after ash deposition was studied by means of pollen analysis, botanical macro-remains analysis and malacology. AMS dating of material of terrestrial origin provided reliable dates in addition to the date provided by the ash. For the Ricci pit, an archaeological study was carried out, following the discovery of Bronze Age artefacts in this pit.

2.2 Ricci

At Ricci an 83 cm thick layer of peat was exposed beneath a 203 cm thick deposit of reddish-brown loams with a coarser textured core, representing a filled-in river bed and associated levees. These loams consist of eroded soil material that has largely retained the colour and (micro)structure of the mountain soils from which it originates, and are ascribed to man-induced soil erosion starting in the Late Bronze Age to Early Iron Age (Sevink *et al.* 1984; Van Joolen 2003; Feiken 2014). As regards the peat deposits below, these are in the transitional zone between the calcareous lacustrine deposits and pyritic black clays mentioned earlier and formed in the delta of a river that ran into the lake from the NW (NW of the pit) and adjacent truly lacustrine environment (SE of the pit). The AV ash was detected at a level 211 cm below the surface, that is just within the peat. The pit was sampled by cutting 1 cm thick samples directly from the SE section wall, neglecting the loam deposits on top and starting with the uppermost organic layer. An AMS date obtained from the depth of 248 cm below surface revealed an age of somewhere between 2471 and 2213 calBC, which is before the start of the Bronze Age (GrA-56801, 3885 ± 35 BP, *Schoenoplectus* seeds). Higher up, at 218 cm but still below the AV ash, an AMS date was obtained of 2131-1779 calBC (GrA-56630, 2600 ± 45 BP, *Alnus* seed and catkin). As the aim of the investigation was to study the Bronze Age, pollen analysis focused on the upper 50 cm of the peat.

Thirteen samples were selected for analysis. For the extraction of pollen the samples were treated with 10% KOH, HCl, Bromoform/Ethanol s.g. 2.0 and acetolysis. Before treatment, tablets with *Lycopodium* spores were added following the method Stockmarr (1971). The residue was mounted in glycerine-gelatine. After identification and counting, a pollen diagram was drawn using the TILIA and TILIAView programs (Grimm 2011). Identification was based on Beug (2004) for pollen and spores, and Van Geel (2001) and Van Geel *et al.* (2003) for non-pollen palynomorphs. Pollen identified as cereal pollen have diameters > 36 μm and an annulus as broad as the pore diameter with a sharp demarcation towards the pollen grain's surface (Grohne 1957).

The pollen sum is an upland (dryland) sum. All taxa that could have grown locally were excluded. As the peat was mainly alder carr peat it is obvious that *Alnus* and other trees growing in wetlands had to be excluded as well. The number of pollen and spores aimed at to include in the sum was 300, but in two cases this number was not reached. In addition to pollen etc., micro-charcoal was counted following the method for microscopic charcoal in pollen slides advised by Mooney and Tinner (2010/2011), which means counting only black, opaque, angular fragments of more than 10 μm length.

Detection of a gully in the top of the peat in the NW wall, filled with an organic deposit consisting of reworked peaty material, plant macro-remains, molluscs and other material led to sampling for this kind of material. The fill of the depression was sampled at four locations, total sample volume 11 litres, sieved with tap water on sieves with meshes up to 0.25 mm, and subsequently analysed.

During inspection of the large Ricci basin, not only palaeo-ecological samples were taken but also three ceramic fragments and one bone fragment were salvaged. One nearly complete vessel was found on the spoil heap resulting from the emptying of the gully mentioned earlier (fig. 3a). Two ceramic fragments and one bone were found in the section, directly below the AV layer, in the NW wall. The bone is a human bone. The finds led to a small excavation comprising two test pits, pits 1 and 2, 22 m^2 and 31 m^2 respectively next to the rim of the Ricci pit.

From test pit 1 no archaeological material was recovered. The AV layer was visible in the section and some tree branches were found, which did not look natural.

In test pit 2 a number of ceramic sherds were found (fig. 3b). Since the AV was not visible in this pit, the finds could not be related to this layer. Also in this pit was a layer with tree branches.

2.3 Mezzaluna

The sediment encountered at Mezzaluna is representative of the lacustrine deposits mentioned before. A freshly cleaned side of a small drainage channel provided an opportunity to take samples for pollen and mollusc analysis. Up to 67 cm below the surface samples could be taken directly from the section wall. Deeper samples were obtained by coring with a side-filling corer. At 111 cm below the surface coring was stopped by an impenetrable log. The upper 32 cm consisted of peat. Below this, a whitish lake marl stood out. The AV ash was visible as a 1 cm thick band at a depth of 63 cm below the surface (see fig. 2). The deposit of lake marl ended at 79 cm, to change into carr peat.

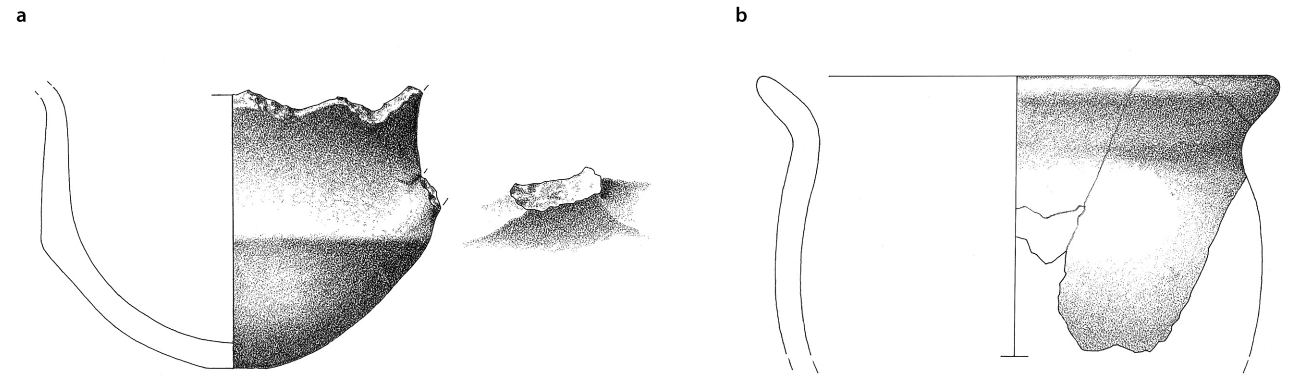

Figure 3. The ceramics found at Ricci. Max. diameter a 12 cm, b 14.5 cm; drawing C. Anastasia and R. Timmermans

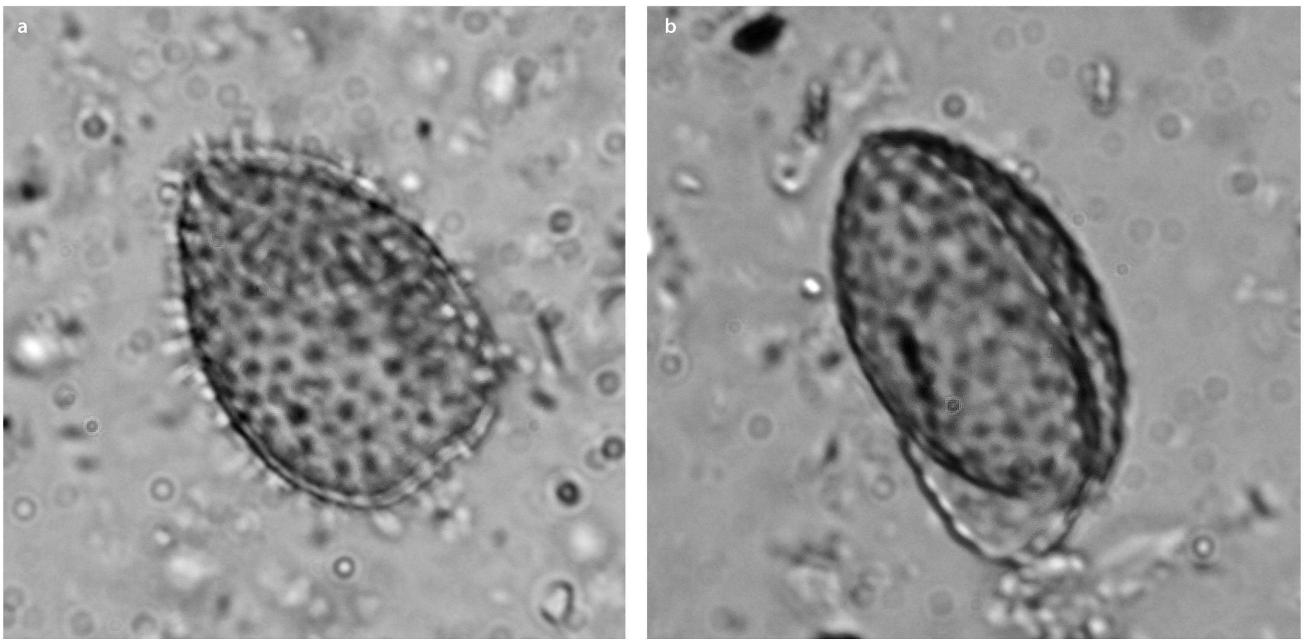

Figure 4. Non-pollen palynomorphs, left type a and right type b, photos C. Bakels

Section and core were cut up into slices of 1 cm thickness. Fourteen were selected for pollen analysis and treated in the way described before, though an adjustment was made to the content of the pollen sum: *Myrtus* was excluded because the pollen grains of this dryland shrub are so dominant in the lowest spectra that they distort the picture.

Two non-pollen palynomorphs, which turned up in rather important numbers, could not be ascribed to known NNP types (van Geel pers. comm.). Non-pollen palynomorph type a is brownish hyaline, oval, 35 by 25 μm and provided with 2 μm long spines. Type b is also brownish hyaline, oval, 25 by 20 μm but provided with scabrae (fig. 4).

To retrieve botanical macro-remains and molluscs samples were taken from the base of the upper peat layer (sample 1), the lake marl (samples 2-6) and the top of the underlying peat (sample 7). The sample volume amounted to two litres. After sieving with tap water on sieves with meshes up to 0.25 mm the residue was analysed with the use of a microscope.

3 Results

3.1 Ricci

Figure 5, table1 and table 2 present the results.
In figure 5 pollen, spores and non-pollen palynomorphs are depicted in percentages, charcoal in particles per cm^3. The diagram suggests three local pollen zones.

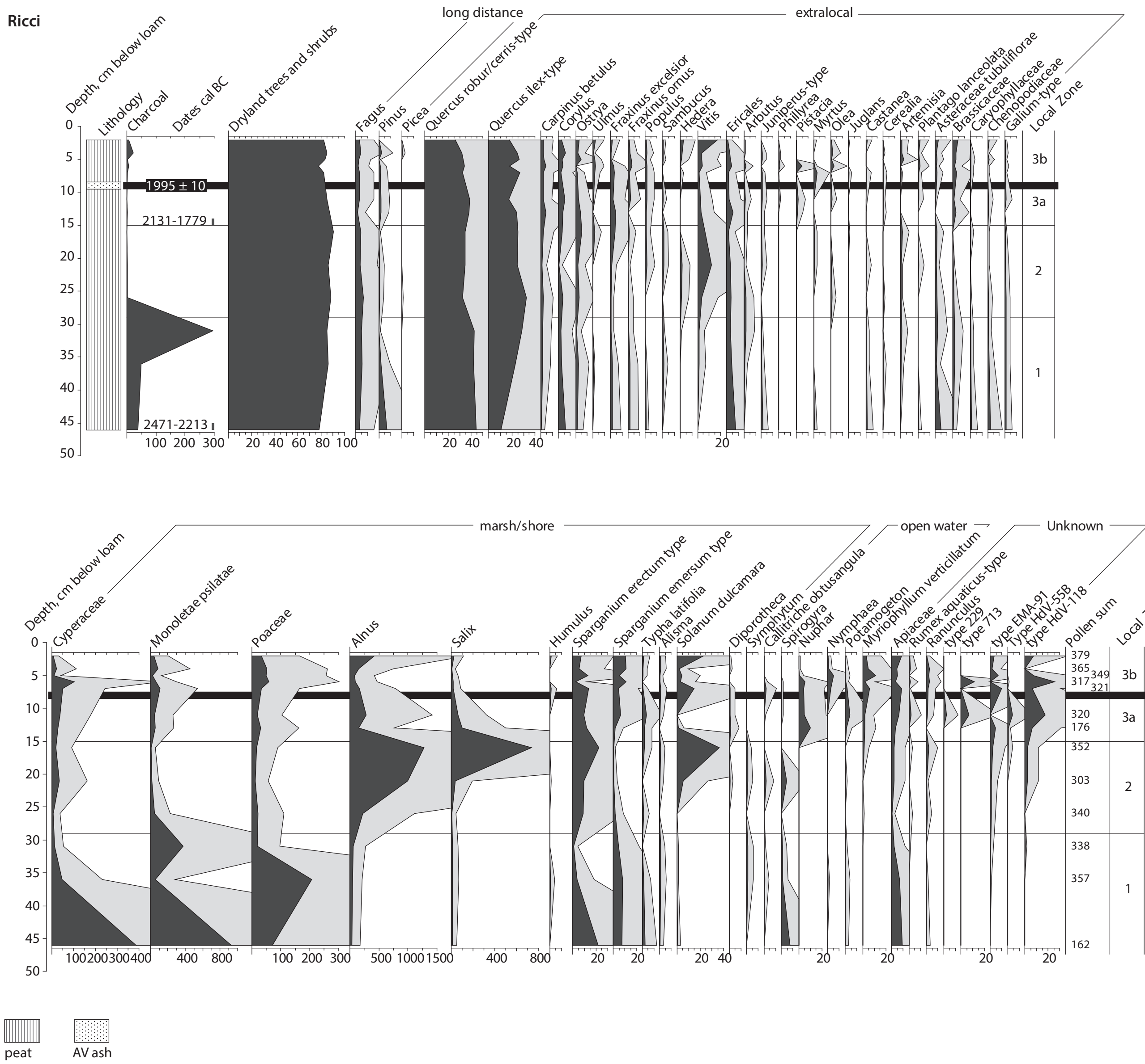

Figure 5. The Ricci pollen diagram, exaggeration of curves 5x in grey; the heavy horizontal line indicates the position of the AV ash

In *zone 1* dryland trees and shrubs are present with percentages between 75 and 80. Although it is difficult to estimate the cover of forest versus open land from this kind of data, the percentages allow the assumption that open spaces were present close to the lake (Sugita *et al.* 1999). Some trees are not supposed to have grown in the Agro Pontino area, because they belong to vegetation types in more elevated positions, *i.e.* mountains (*Fagus*, *Picea*), or in a coastal zone (*Pinus*) (Pignatti 1982). The vegetation in the area itself was dominated by oak species, deciduous and evergreen. Of the deciduous oaks both *Quercus robur*-type and *Quercus-cerris* type are present, but as part of the pollen could only be identified as *Quercus robur-cerris type*, these are taken together. The *Quercus cerris*-type also includes the evergreen cork oak *Quercus suber*. *Quercus ilex*-type stands for the evergreen oaks *Quercus ilex* and *Q. coccifera*. *Carpinus betulus*, two kinds of ash, *Fraxinus excelsior* and *Fraxinus ornus*, and *Corylus* are continuously present as well, as is chestnut, *Castanea*. Elements of secondary shrub vegetations show that the original landscape was already

Pollen and NPP not in diagram	Ricci	Mezzaluna 3
Trees		
Acer	21=0.3	35=1.0; 50=0.3; 90=0.3; 100=0.4
Betula	2=0.3; 4=0.3; 6=0.3; 7=0.3; 11=0.3; 13=0.6; 36=0.3	40=0.5; 55=0.4; 65=0.9; 85=0.4; 100=0.4
Buxus	11=0.3	
Celtis	4=0.3;13=0.6	50=0.3; 60=0.6;
Cornus sanguinea	7=0.3;11=2.2	
Malus-type	11=0.6	90=0.6; 100=0.4; 110=0.9
Platanus	11=0.6	
Sambucus	in diagram	40=0.3; 90=0.3
Sorbus-type	6=0.3	
Tilia		35=1.0
Shrubs		
Cistus salvifolius/monspelianus		65=0.3
Genista-type	2=0.3;31=0.3	
Hippophae		55=0.2
Rhamnus	2=0.5; 6=0.6 ;7=0.9; 11=0.6; 16=0.6; 21=3.6; 31=0.6	35=0.3; 45=0.3; 55=0.2; 85=0.8; 90=0.6; 110=1.7
Tamus	5=0.3; 7=0.6	
Viburnum	31=0.3	90=0.6
Upland herbs		
Asteraceae liguliflorae	2=0.8; 7=0.6; 13=0.6; 21=0.3; 36=0.8	in diagram
Asteraceae tubuliflorae	in diagram	40=1.6; 50=0.3; 60=0.6; 65=0.6; 90=0.3; 100=0.4
Gagea-type		74=0.3
Galeopsis/Ballota	4=0.6	
Galium-type	in diagram	45=0.3; 50=0.3; 90=0.6; 100=0.4
Hedysarum		60=0.3
Helianthemum nummularium		90=0.3
Hypericum perforatum	4=0.3; 11=0.3; 16=0.3	45=0.5; 50=0.3
Lamium-type	7=1.9; 16=0.9	
Lithospermum arvense	36=0.3	
Lygeum	21=0.3	
Plantago major/media-type	4=0.6; 7=0.6; 16=0.6;	40=0.3; 45=0.3; 80=0.3
Polycarpon	31=0.6	
Polycnemum	11=0.3	45=0.5
Polygonum aviculare	2=0.3; 11=0.3; 31=0,3; 36=0.6; 46=0.6	80=1.0; 90=0.6
Polypodium	21=0.7; 31=0.6; 36=0.6	
Prunella-type	2=0.3	
Rumex acetosa-type		45=0.3; 70=0.3
Salvia officinalis-type	5=0.3	
Scabiosa		74=0.7
Spergularia	2=1.3; 7=0.6	in diagram
Trifolium	5=0.3	40=0.3; 90=0.3; 100=0.7

Pollen and NPP not in diagram	Ricci	Mezzaluna 3
Vicia	5=0.3; 11=0.9	
Viola		55=0.2
Wetland herbs		
Butomus	4=0.6; 31=3.0; 36=0.3	
Caltha-type	7=0.6; 21=1.3; 31=0.3; 36=0.8	60=0.3
Cladium	2=0.3; 4=0.6; 5=0.6	
Filipendula	4=0.3; 6=0.6; 11=0.6; 46=0.6	35=0.3; 50=1.6; 70=0.5; 80=0.3
Lysimachia	2=0.3; 6=0.6; 7=0.9; 16=1.7; 21=1.3; 31=0.6; 36=0.3	40=0.5; 100=0.4
Valeriana officinalis	5=0.3	100=0.4
Aquatic herbs and algae		
Elatine	16=0.3	
Lemna	36=0.6	85=0.4
Myriophyllum spicatum	2=0.6; 5=0.3; 13=0.6; 16=0.3; 31=0.6	45=0.3; 50=0.5; 55=0.4; 60=0.3; 70=0.5
Nuphar		45=0.3; 80=0.6; 85=0.4
Nymphaea		35=0.4; 55=0.2; 60=0.6; 65=0.3; 90=0.3
Mougeotia	46=3.7	45=1.1; 50=0.5; 55=0.2; 80=0.3
Pediastrum		65=0.3; 74=1.0
Zygnema	6=1.0; 46=0.6	55=0.4
Unknown		
Cyperus		55=0.3; 90=0.6
Iris		85=0.4
Lotus	46=0.6	
Lythrum-Peplis	2=0.5; 5=0.3; 6=0.3; 7=1.3; 26=0.3	
Mentha-type	5=0.3; 6=0.3; 7=0.3; 13=0.6; 16=0.6	
Persicaria maculosa-type	21=0.3; 26=0.6	80=0.3
Scrophularia	31=0.6	
Stachys-type	11=0.3; 36=0.6	40=0.3
Urtica	2=0.3; 7=0.3; 11=0.3; 16=0.3	
Veronica	2=03; 7=0.3	40=0.3
Tetraedron		40=0.8; 45=0.5; 55=0.9; 65=0.3
HDV 55B	6=0.3; 11=4.1; 13=0.6; 16=0.9	
HDV 229	11=2.5	40=0.8; 45=0.3
HDV 501	21=2.3; 26=13.2; 36=0.3; 46=8.0	
HDV 713	6=11.7; 11=6.6	

Table 1. Pollen, spores and non-pollen palynomorphs not depicted in figures 5 and 6; depth=percentage

	Ricci				Mezzaluna 3				
					40 cm	**55 cm**	**ash**	**65 cm**	**75 cm**
sample size, litres	5	2	2	2	2	2	2	2	2
molluscs freshwater species									
running water									
Theodoxus fluviatilis	xxx	xx	xx	xx	-	-	-	-	-
Theodoxus fluviatilis - operculum	x	x	-	x	-	-	-	-	-
Viviparus contectus	x	x	1	1	-	-	-	-	-
Belgrandia latina	xxx	xx	xx	xxx	-	-	-	-	-
Pseudamnicola moussonii	xxxx	xxx	xxx	xx	-	-	-	-	-
Ancylus fluviatilis	x	-	-	x	-	-	-	-	-
Pisidium amnicum - valve	xx & x d	x &x d	x & x d	x	-	-	-	-	-
running and stagnant water									
Bithynia tentaculata	xxxx	xxx	xxx	xxxx	x	x	1	x	x
Bithynia tentaculata - operculum	xxxx	xxx	xxx	xxxx	x	x	x	x	x
Valvata piscinalis	xxx	xxx	xxx	xxxx	-	-	-	-	-
stagnant water (plant rich)									
Valvata cristata	x	x	x	xx	-	-	-	-	-
Bithynia leachiii	x	xx	xx	xx	xxx	xx	xx	xxx	xxx
Bithynia leachii - operculum	x	xx	xx	xx	xx	xx	xx	xx	xx
Acroloxus lacustris	xx	xx	xx	xx	2	-	-	1	2
Lymnaea stagnalis	x	x	x	x	-	-	-	-	-
Radix auricularia	x	x	2	x	-	-	-	-	-
Radix ovata	1	-	-	x	x	x	x	x	x
Stagnicola palustris s.l.	x	x	x	x	1	-	-	-	-
Gyraulus crista	xx	xx	1	xx	x	x	x	x	xx
Planorbis planorbis	x	x	x	x	-	-	-	-	-
Bathyomphalus contortus	-	-	3	-	-	-	-	-	-
Hippeutis complanatus	-	-	1	-	1	-	-	2	1
Unio sp. / Anodonta sp. - valve	xx	x & x d	1	2 d	-	-	-	-	-
Pisidium sp. - valve	xx & x d	xx & xx d	xx & xx d	xx	-	-	-	-	-
molluscs land species					-	-	-	-	-
Carychium minimum	-	1	-	-	-	-	-	-	-
Oxyloma sp.	x	x	1	x	-	-	-	-	-
Vertigo antivertigo	-	-	1	-	-	-	-	-	-
other animal remains									
bone fragment	x	x	-	x	-	-	-	-	-
Arvicola terrestris, jaw	-	-	1	-	-	-	-	-	-
fish remains	x	x	-	x	-	-	-	-	-
Ostracoda	x	xxx	x	x	-	-	-	-	1
insects	x	x	x	-	-	-	-	-	-

	Ricci				Mezzaluna 3				
					40 cm	55 cm	ash	65 cm	75 cm
plant remains									
charcoal fragments	x	x	x	x	-	-	-	-	-
wood remains, twigs, rootlets	x	x	x	x	-	-	-	-	-
cultivated									
Ficus carica	2	2	x	-	-	-	-	-	-
trees, shrubs, dryland herbs									
Alnus glutinosa - seed	x	1	x	x	-	-	-	-	-
Alnus glutinosa - catkin, bud	x	x	1	x	-	-	-	-	-
Vitis sylvestris	x	1	x	-	-	-	-	-	-
Cornus sanguinea	x	2	x	-	-	-	-	-	-
Rubus fruticosus	x	8	x	x	-	-	-	-	-
Solanum nigrum	-	-	-	-	-	-	1	-	-
herbs from marshes									
Carex sp.	1	5	x	1	-	-	-	-	-
Cladium mariscus	x	xxx	xxx	xxx	1	-	1	-	-
Sparganium erectum	x	20	x	x	-	-	-	-	-
Schoenoplectus tabernaemontani	x	3	2	1	-	-	-	-	-
Typha sp.	x	-	1	-	-	-	-	-	-
Lycopus europaeus	-	-	1	1	-	-	-	-	-
Mentha sp.	x	1	x	x	-	-	-	-	-
Solanum dulcamara	1	1	1	1	-	-	-	-	-
Stachys palustris	1	2	1	-	-	-	-	-	-
Eupatorium cannabinum	1	4	x	-	-	-	-	-	-
cf Sium latifolium	2	-	-	-	-	-	-	-	-
Berula erecta	1	-	-	-	-	-	-	-	-
Lamiacea	1	-	-	-	-	-	-	-	-
Apiaceae	-	-	x	-	-	-	-	-	-
cf Persicaria maculosa/minus	2	10	x	-	-	-	-	-	-
aquatic plants									
Ceratophyllum demersum	x	4	x	1	-	-	-	-	-
Chara sp.- oögonium	-	-	-	-	xx	xxx	xx	xxx	xxx
Chara sp. - stemfragment	-	-	-	-	xxx	xxxx	xxx	xxxx	xxxx
Myriophyllum sp.	-	1	-	-	-	-	-	-	-
Nuphar lutea	2	1	1	1	-	-	-	-	-
Nymphaea alba	x	2	x	2	-	-	-	-	-
Potamogeton cf coloratus	x	5	x	x	-	-	-	-	-

Table 2. The molluscs and botanical macro-remains found at Ricci and Mezzaluna 3; x = some, xx = tens, xxx = hundreds, xxxx = thousands, d = doublet

disturbed. Ericales (*Erica* sp.), *Arbutus*, *Juniperus*-type (including *Juniperus* and *Cupressus*) and *Myrtus* belong to this category. *Artemisia*, *Plantago lanceolata* and Cerealia attest to open space. The latter are supposed to represent cultivated cereals, though certain wild grasses release the same kind of pollen. Such grasses mainly grow in dune areas and such areas are present west of the Agro Pontino, but as other elements of coastal vegetation are not very obvious in the pollen record, an explanation of cereal-type pollen as shed by cereals is considered most likely. The local vegetation in the lake at the place of sampling is a marsh vegetation of first Cyperaceae (sedges), Monoletae psilatae (ferns), *Sparganium* species, *Typha latifolia* and *Alisma*, followed by Poaceae (grasses including reed) and *Symphytum*. Open water is hardly present. The alga *Spirogyra* can grow in very shallow water. Charcoal is continuously present.

Local *zone 2* shows a slight decline in the group of tall oaks (deciduous and cork oaks), an initial rise in *Quercus ilex*-type oaks followed by a decline, and an increase in the percentages of other taxa such as *Populus*, *Fraxinus* species and the lianas *Hedera* (ivy) and *Vitis* (vine). This is an indication that the dryland oak forests suffered a decline. More light offers lianas better chances of flowering. Pollen does not provide a clue whether the vine was wild or cultivated, but pips discovered amongst the macro-remains in the uppermost part of zone 3 are of the wild type (see below). The same question, cultivated or not, is raised by *Olea* (olive) and *Juglans* (walnut), which appear in this zone. These trees belong to the OJC group, *Olea*, *Juglans*, *Castanea* (chestnut), which at present are all considered indigenous in Italy, but are also known to include cultivated varieties (Mercuri *et al*. 2013). *Castanea* is already present during zone 1. It is questionable whether the low pollen percentages represent cultivation. But the curves of the OJC group tend to rise everywhere in Italy from the Bronze Age onwards and it is quite possible that part of the Ricci pollen has an origin in human cultures.

The vegetation in this part of the lake develops into an *Alnus* (alder) carr, which in its turn is followed by *Salix*. Usually *Alnus* carr is the last stage of the natural succession. Therefore, something must have happened here, either in a natural way or induced by human action, but as there are no indications of a natural cause in this phase of the history of the lake, such as a change in water level, an anthropogenous trigger is the most likely explanation. The alder carr disappeared to make way for a marsh with not only *Salix*, but also *Sparganium*, *Typha latifolia* and a locally abundant growth of *Solanum dulcamara*. Together with *Solanum dulcamara* the non-pollen palynomorph *Diporotheca* appears. It has been suggested that *Diporotheca* is a parasite on *Solanum dulcamara* (Hillbrand *et al*. 2012), a suggestion supported by the Ricci diagram.

Zone 3 shows even more disturbance in the upland part of the diagram. *Phillyrea* and *Pistacia* appear and *Myrtus* has an optimum. In the wet basin all tree and shrub vegetation has vanished. The *Alnus* pollen percentages are considered to have come from stands further away. The lake is now filled with open water in which *Nuphar*, *Nymphaea* and *Myriophyllum* flourished. This zone started somewhere after 2131 calBC, but before the deposition of the AV ash dated to 1995 ± 10 calBC. The AV ash appears halfway. The pollen record offers no reason to draw another zonation line at the depth of the ash, which implies that no large-scale changes are observed. The only substantial changes are shown by the curves of *Hedera*, *Vitis*, *Olea*, *Artemisia*, *Plantago lanceolata* and charcoal. Charcoal was almost absent during zone 2 and the pre-AV part of zone 3. An increase in human activity is indicated, either in the entire area around the lake, or only locally as a result of an intensification of activities near the Ricci pit. But there is no question of a striking difference due to a large-scale influx of new people after the eruption. The most important change in the landscape is the disappearance of the carr some time before the AV event.

The results of the macro-botanical analysis match those obtained by pollen analysis. Some taxa that were not indicated by their pollen are identified with more precision, such as the Apiaceae cf. *Sium latifolium* and *Berula erecta*. The *Vitis* pips mentioned earlier display the diagnostic features commonly associated with wild grapevine (Jacquat and Martinoli 1999) and may, therefore, be classified as wild, though there is an overlap between the identification criteria of wild and cultivated vine.

The samples from the gully in the top of the peat were remarkably rich in molluscs. It is clear that we are dealing with a freshwater fauna. Of the 21 species five are restricted to running water. Two species deserve special attention. *Pseudamnicola moussonii* is widespread throughout Italy, mainly in its western and southern regions, including Sicily and Sardinia. The mollusc prefers streams and rivers (www.iucnredlist.org). *Belgrandia latina* is endemic to Italy, and only found at some locations in the Apennines region of Lazio. This small spring-snail lives in deeper freshwater lakes and their tributary streams and outflows fed by spring water (www.iucnredlist.org). The mollusc is especially characteristic of situations of calcareous upwelling water.

Three other species are also characteristic of running water. Some other animals, such as *Bithynia tentaculata* and *Valvata piscinalis* (both with large numbers) occur both in flowing and standing water. The others indicate the presence of marshy shorelines. Regular fluctuations in the water level are not indicated.

Only three species of land snails were found. These animals live under wet conditions. In this case, they point to the presence of a marshy riparian zone along the water.

Together with the shells some pieces of bone, a molar of the watervole *Arvicola terrestris*, pieces of fish (tooth, vertebra, scale), insect fragments and, in larger numbers, ostracods valves were retrieved.

The dating of the archaeological finds was problematic. One of the main problems of Bronze Age studies in Central Italy is the absence of an absolute chronological framework (Van Rossenberg 2012, 9). There are many radiocarbon dates available for the Copper Age, the Middle Bronze Age (MBA) and later periods, but especially for the Early Bronze Age (EBA) absolute dates are scarce (Van Rossenberg 2012, 67). The dates that are available from EBA sites in Central Italy do not fit in the traditional EBA range (see Pacciarelli 2000, 68; Feiken *et al*. 2012, 115; van Rossenberg 2012, 9) and are considered anomalies but Van Rossenberg (2012, 67-72) is questioning this explanation.

So far the only absolute dates for the EBA we have in the Agro Pontino are for the ash layer from the Avellino eruption dating from 1995 ± 10 calBC established by ^{14}C dates from over and underlying organic materials (Sevink *et al*. 2011), and ^{14}C dates from Tratturo Caniò (Feiken *et al*. 2012) and Ricci.

The vessel from the gully could be dated on typological grounds as EBA II or MBA I (Pacciarelli 2000). The typological dating is problematic because both the rim and the handle of the vessel are missing. The vessel seems comparable to objects in Pacciarelli figure 9, C 7-10 (Pacciarelli 2000, 26), facies di Palma Campania and figure 11, C 4 (Pacciarelli 2000, 29), facies protoappenninico 1. The facies Palma Campania dates from 2100/2000 – *c*.1800 calBC and the facies protoappenninico from *c*. 1800 - 1550/1500 (Pacciarelli 2000, 68). The two other ceramic fragments from the water reservoir were dated typologically as EBA II.

Since the AV layer is dated to 1995 ± 10 calBC (Sevink *et al*. 2011) and the EBA II is dated by Pacciarelli (2000, 68) from 2100/2000 – *c*.1700 calBC, the two ceramic fragments must have a date between 2100/2000 and 1995 calBC.

Wood fragments from inside the vessel give a ^{14}C date of 1882 – 1681 calBC (GrA-51750). This date could be used as a terminus ante quem, and the vessel must thus be older than 1681 calBC. This would mean EBA II (2100/2000 – 1700) or MBA I (1700 – 1550/1500). We do not know the original position of the vessel compared to the AV layer.

The ceramic fragments from test pit 2 do not have any diagnostic features and could be roughly dated to the Bronze Age or the Middle Bronze Age.

The finds at Ricci prove that the site was used in the EBA II and/or MBA I. The human bone and the (almost) complete vessel suggest a burial or at least a funeral rite. However, this was not confirmed by finds from the test pits.

The not very precise date makes it impossible that these finds play a significant role in the discussion of the mass migration as a consequence of the Avellino eruption. All we can say for certain is that the site was in use before the eruption (the two ceramic fragments from the water reservoir come from below the AV layer), but the site could also have been used after the eruption (the vessel from the reservoir and the ceramic fragments from the test pits date on typological grounds to EBA II or MBA I). That could be shortly after the eruption or hundreds of years later.

3.2 Mezzaluna

The vegetation history told by the Mezzaluna section resembles that of the Ricci section (fig. 6, table 1 and table 2). Its lowest pollen zone corresponds with Ricci zone 2. Both deciduous and evergreen *Quercus* species are dominant in the area, whilst *Ulmus*, two kinds of *Fraxinus*, *Hedera* and *Vitis* are present as well. The OJC complex is present in low percentages. The end of this zone is expressed in the dryland by a rise in pollen percentages of *Ostrya* and a decline in *Ulmus* and *Vitis*, but more striking is the decline in wetland trees, *Alnus* followed by *Salix*. The end of zone 2 is also the end of carr peat formation. Striking too is the disappearance of *Solanum dulcamara* and *Diporotheca*.

Local *zone 3* represents a clear freshwater lake with, amongst others, *Callitriche obtusangula* and *Utricularia*. The deposit in this lake changed into an almost white lake marl, revealing also many needles of freshwater sponges and oögonia of *Chara*. The AV layer is situated halfway.

If an influx of new people had affected the environment on a large scale, it should be visible in the lake marl part of the diagram. However, dramatic changes are absent, except for a strong rise in the non-pollen palynomorphs type a and type b, and a rise in charcoal. *Alnus* pollen percentages decline, but these values were already declining in the pre-AV stage. In the dryland, tall *Quercus* declines and *Olea* and Cerealia are more important than before. The trend in the curve of tall oak is different from what is observed in the Ricci case where those trees show a decline that started already before the AV event. Only the curves of *Olea* and charcoal show trends matching those seen in Ricci.

The peaty samples did not present identifiable plant macro-remains. In the lake marl the most abundant taxon is *Chara* sp. found as oögonia (macrospores) and marl encrusted stems. Luxurious *Chara* growth is characteristic of clear fresh water rich in chalk and its appearance tallies with the presence of lake marl. The other plant remains identified are from *Cladium mariscus* and *Solanum nigrum*.

The peat revealed no molluscs and the fauna of the lake marl is remarkably low in species. Seven species were found, including three with only some individuals. The others (mainly *Bithynia leachii*) were found with higher numbers.

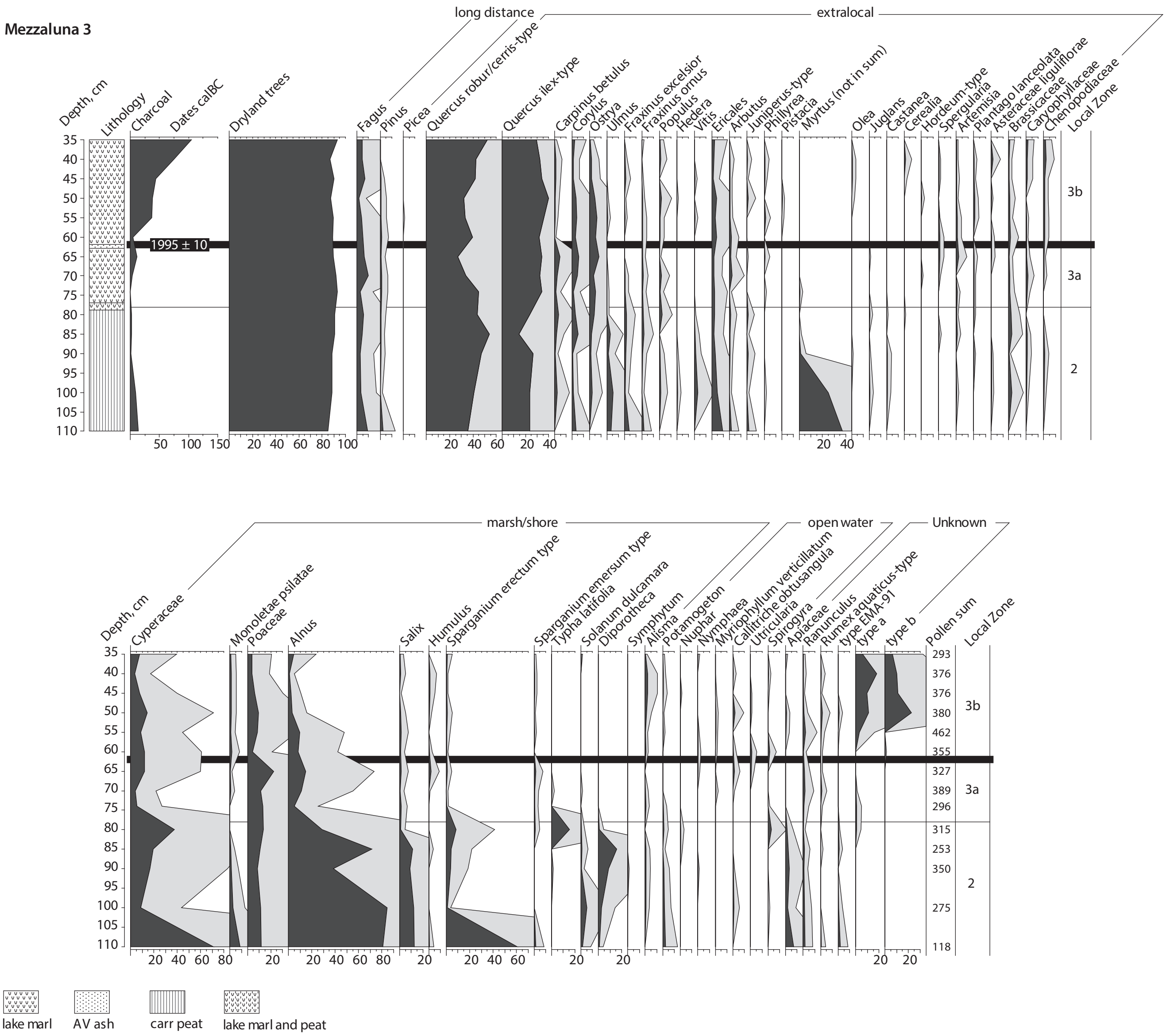

Figure 6. The Mezzaluna 3 pollen diagram, exaggeration of curves 5x in grey; the heavy horizontal line indicates the position of the AV ash

The species live in fresh water and are distributed all over Europe. The fauna indicates shallow, but not drying up, stagnant water. The water was clear and well provided with vegetation.

The absence of other aquatic animals in the lake marl is striking. Only in sample 6 a valve of an ostracod was observed. Both plant remains and molluscs do not give an indication concerning changes in the environment before and after the AV event.

Taking the results from the Mezzaluna site together, the conclusion must be that traces of human influence are not very strong, but after the AV event there seems to have been a slight enhancement in human interference.

4 Discussion and conclusion

Both the Ricci and Mezzaluna pollen diagrams show that the landscape surrounding the lake was already disturbed by human activities before the deposition of the AV-tephra. In the dryland part of the landscape the original forest, dominated by oak, had already to some extent been replaced by secondary shrub vegetations. In the wetland bordering the lake human interference was of a serious character. The disappearance of the alder carr is held to be of anthropogenic origin, as there are no clues that natural causes such as a change in hydrological conditions may have been responsible. Everywhere the peat in the basin, mainly alder carr peat, shows traces of repeated burning (Feiken *et al*. 2012). Burnt patches were also present in the Ricci pit and a piece of charcoal embedded in such a patch was dated 2135 - 1912 calBC (GrA 56678). Throughout the former lake somewhere below the AV-layer, generally only a few decimetres, remains of trees in the form of logs and thick branches abound, commonly embedded in the peat below the lake marls. Exposures are generally too limited in size to allow for detailed observations on the spatial distribution of logs and their mode of origin, but at Campo Inferiore a series of large trenches was dug, exposing many large wood remains. Virtually all logs and thick branches were free of bark and smaller branches, and many had been shaped into squared timber, showing clear traces of working. Some were sharpened at one end. Because of these characteristics, it was concluded (Anastasia, unpublished report for the Soprintendenza; Sevink *et al*. 2011) that during the Early Bronze Age trees, mainly alder and willow, had most likely been felled on purpose and subsequently been worked. But for some unknown reason timber had been left on this site, which was in the marsh. The burning and logging has to be attributed to the Early Bronze Age inhabitants of sites bordering the lake, of which unfortunately only Tratturo Caniò is truly known so far (Feiken *et al*. 2012).

The conclusion is that the land surrounding the lake was inhabited by an Early Bronze Age population which is not yet well known, but which already had a significant impact on the natural environment before the Avellino eruption. Whether the land immediately bordering the lake was inhabited everywhere by Bronze Age farmers cannot be established on the basis of the current palaeoecological data only. However, it is very likely that the marshy stagnant southwestern margin of the graben was probably far less attractive than the northeastern one, a hypothesis that might be checked by future systematic coring of this ‘hidden landscape’. There may have been relatively empty space but, if many people from Campania had fled to the Agro Pontino graben and had started a new life there, the impact of this event should be visible both in pollen diagrams and in the archaeological record. Up to date, the latter does not provide any information. The pollen diagrams Ricci and Mezzaluna 3 show a slight increase in the indications of human interference with the landscape, but these may also be attributed to a natural increase of the indigenous population. Of a mass immigration of people coming from elsewhere, there is no trace. Either investigations are still too limited in scale and number, or the population from Campania found asylum elsewhere. The first possibility is certainly true and the second needs to be explored.

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