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Photograph of the cleaned bank of the freshly dug ditch north of Wartena (the province of Friesland, the Netherlands. Photo T.W. Varwijk (RUG/GIA)).

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Vegetation reconstruction of the Agro Pontino and Fondi basin (central Italy) before and after the Bronze Age eruption of Somma-Vesuvius (c. 1900 BCE)

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Abstract: In the research project *The Avellino Event: Cultural and Demographic Effects of the Great Bronze Age Eruption of Mount Vesuvius*, the recording of local and regional changes in the vegetation of the landscapes of the Agro Pontino and the Fondi basin (southern Lazio, Italy) before and after the Bronze Age eruption of Somma-Vesuvius (c. 1900 BCE) was central to answer the project's central question, which revolved around the nature of the distal effects of this high-magnitude eruption on the conditions of living for the Bronze Age human population inhabiting these landscapes. If adverse effects of the ash fall in these areas were minor, the Agro Pontino and the Fondi basin, located about 125 km north of the Vesuvius, could well have been the refuge area people might have fled to in their attempts to escape the pyroclastic flows that eventually would bury parts of Campania around the Vesuvius below a thick layer of tephra. If adverse effects of the ash fall were major, the situation might, likewise, have led to changes in vegetation but could have resulted in a decline in human and animal presence due to toxicity, for instance. In both scenarios, either population growth due to in-migration or population decline due to environmental impact, we expected to see changes in the vegetation record in the period during which the Avellino Event occurred. To test our hypotheses, we performed archaeobotanical research, using pollen and macro-remains, on stratified soil sequences from test pits in the Agro Pontino and the Fondi basin containing the Avellino tephra layers, thereby guaranteeing sound chronological control. (The research revealed the presence of other known distal tephtras as well.) Contrary to our expectations, the research did not provide proof of any significant changes in the vegetation around the date of the Avellino Event, nor did it provide any strong signs of human impact on these landscapes in the longer term before and after the distal ash fall, thereby indicating low population levels during the final part of the Early Bronze Age (EBA) and the initial phase of the Middle Bronze Age. Although this finding about human impact is an important outcome, it is not the only finding. The archaeobotanical research provided the project with high-resolution information on the vegetation and environmental conditions in the Agro Pontino and the Fondi basin for the duration of the Bronze Age. This, in combination with the physical-geographical data collected during the project, added significantly to our ability to perform detailed palaeogeographical reconstruction of the Agro Pontino and the Fondi basin. In addition, it increased our understanding of how the landscape had been settled during the Bronze Age (Sevink et al. 2022; Attema et al. in press). A final spin-off consisted of possible new information on the 4.2 ka climatic event that impacted Italy during later prehistory, as reflected in the pollen diagrams presented.

Keywords: vegetation reconstruction, human impact, distal volcanic impact, Bronze Age, Agro Pontino, Fondi basin, Avellino volcanic eruption, tephra, central Italy.

1. Introduction

The Bronze Age Avellino eruption of Somma-Vesuvius, dated around 1900 BCE, took place in several phases, implying that people living near the volcano must have had the chance to escape the pyroclastic flows (Cioni et

al. 2000; Sulpizio et al. 2008). Indeed, excavations of well-preserved Bronze Age sites from the high-impact zone in Campania, Italy, have revealed only a few human bodies. Albore Livadie et al. (1998) and Di Lorenzo et al.

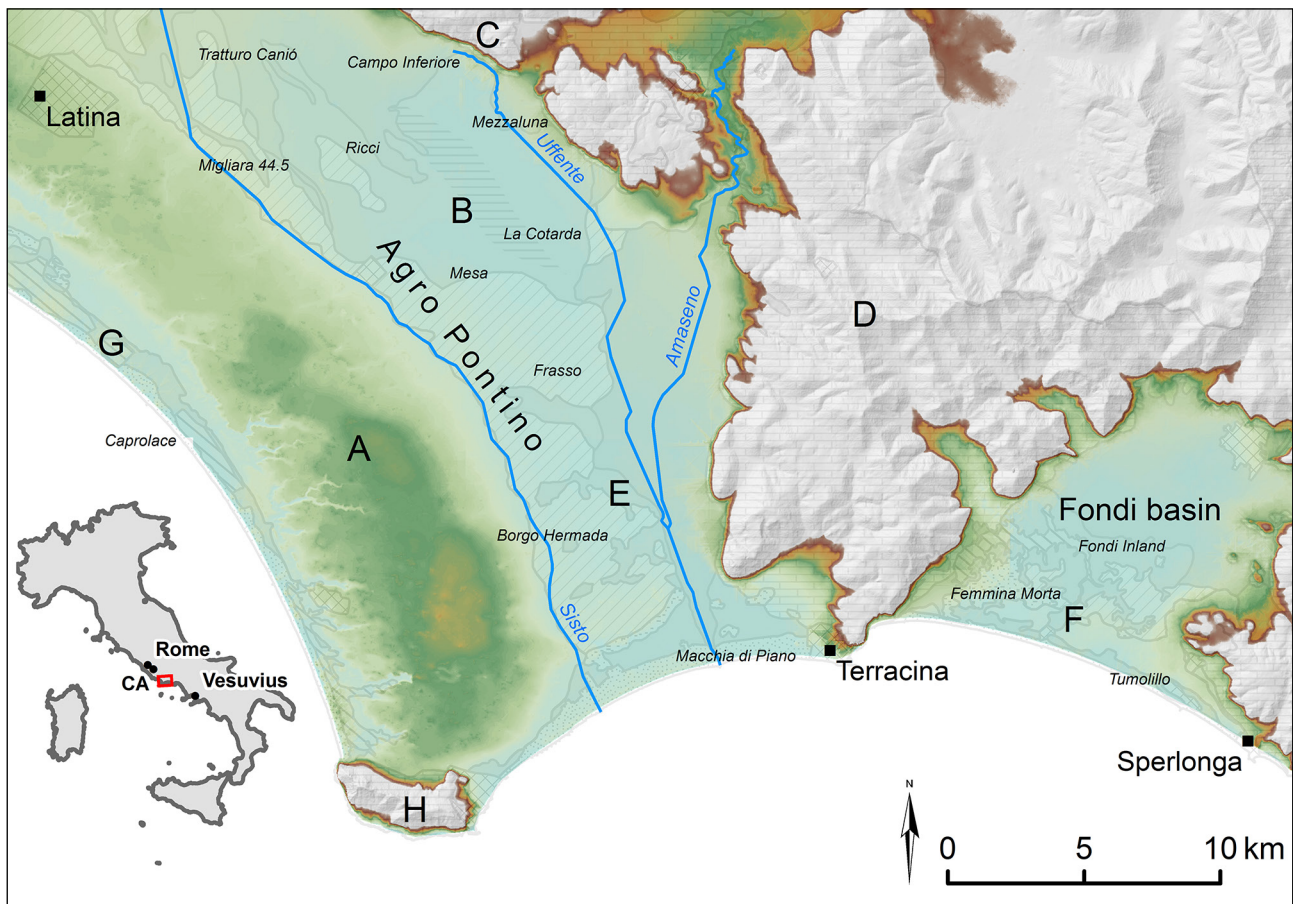


Fig. 1. Map showing the location of the sampling areas. A = higher complex of Pleistocene marine terraces; B = inland Agro Pontino graben; E = south-eastern Agro Pontino graben; F = coastal Fondi; G = western coastal area. Inset: location of the study area with respect to Mount Vesuvius. CA = Colli Albani (graphic Wouter van Gorp, GIA).

(2013) conclude that it took several centuries before the area impacted by the eruption returned to pre-eruption population densities, although recent estimations indicate a much shorter period (Albore Livadie 2019). Where would Bronze Age people from Campania have settled after having fled from the immediate surroundings of the Somma-Vesuvius complex after the Avellino eruption? The hypothesis formulated in the research project *The Avellino Event: Cultural and Demographic Effects of the Great Bronze Age Eruption of Mount Vesuvius* was that a significant proportion of the refugees could have decided to settle in the coastal areas nearest Vesuvius, being the Fondi basin and the Agro Pontino, in southern Lazio, Italy (Fig. 1). In-migration of people into the Agro Pontino and the Fondi basin from Campania, if substantial, could, according to the project's hypothesis, have had a long-lasting effect on the existing vegetation. The project therefore aimed to use changes in the vegetation after the Avellino Event as a suitable proxy, in combination with the physical-geographical and archaeological evidence (for environmental changes in the Agro Pontino in general, see Sevink *et al.* 1984, 2011; Van Joolen 2003; Eisner and Kamermans 2004; Feiken *et al.* 2012; Bakels *et al.*

2015 and for archaeological approaches, see Alessandri 2013). The discovery by Sevink at several locations (for instance at Ricci and Mezzaluna) that the sediments of the Agro Pontino and the Fondi basin contain tephra from the Avellino eruption meant that the project had at its disposal a precise chronological marker for pinpointing any changes in the vegetation in time. Because earlier archaeobotanical research in the region, published by Bakels *et al.* (2015), had not yet yielded sufficient evidence to either confirm or reject the hypothesis of in-migration of people from Campania, we obtained additional samples from stratified soil deposits in the Agro Pontino and the adjacent Fondi basin containing the Avellino tephra. The project's archaeobotanical approach consisted of the analysis of pollen and macroremains in soil sequences below and above the volcanic ash of the Avellino eruption. Archaeobotanical remains are well preserved in the former wetlands of the Agro Pontino and the Fondi basin and proved to be a fundamental component of the project's multi-proxy approach to testing the hypothesis of human impact on the vegetation of the Agro Pontino and the Fondi basin due to in-migration from Campania. In the following, I present the results from six locations.

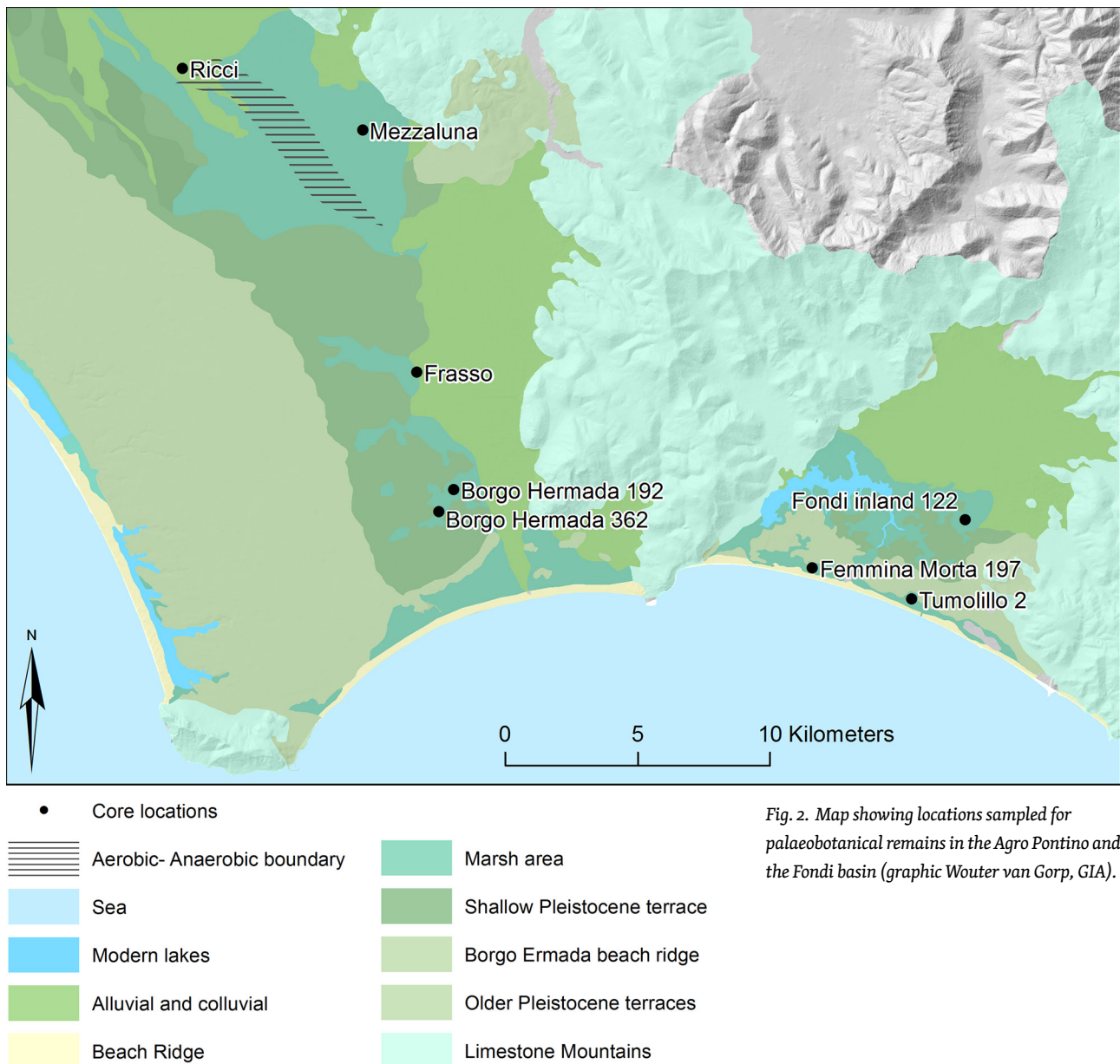


Fig. 2. Map showing locations sampled for palaeobotanical remains in the Agro Pontino and the Fondi basin (graphic Wouter van Gorp, GIA).

2. Sampling locations, material and methods

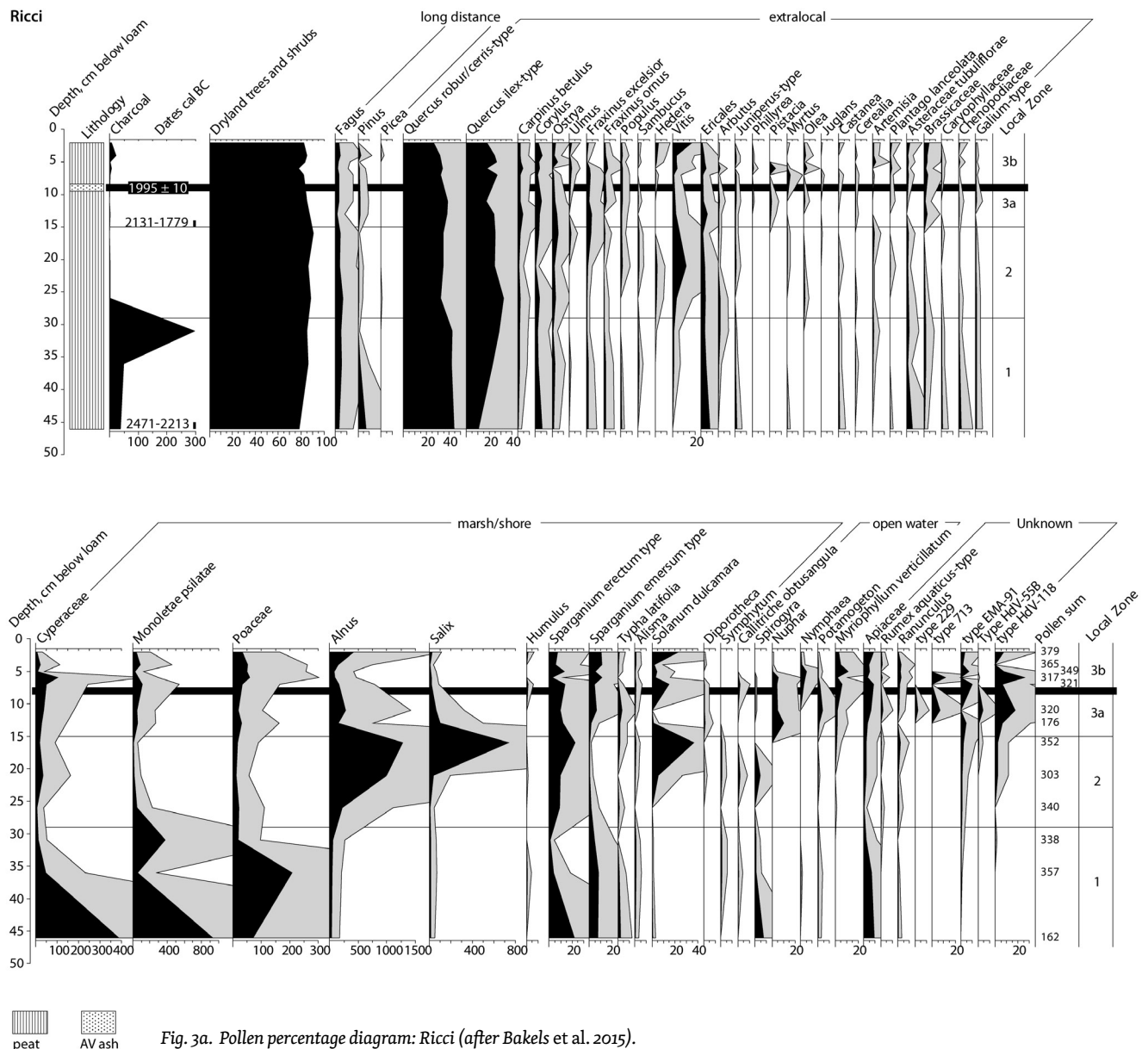
2.1 Site selection

The vast Agro Pontino plain and much smaller Fondi basin are wetland areas in the coastal zone of southern Lazio. Extensive landscape archaeological research conducted in various Dutch projects since the 1970s has generated detailed knowledge of these wetlands' Holocene landscape evolution. In the Avellino Event project, this has resulted in a detailed palaeogeographical reconstruction of the Bronze Age landscape (Van Gorp & Sevink 2019, in press). At the outset of the project, Sevink carried out corings to identify locations suitable for archaeobotanical sampling of stratified deposits containing the Avellino tephra. Ultimately six locations

were considered suitable for sampling (Fig. 2). Before I discuss the results, I describe the landscape of the Agro Pontino and the location and nature of the three sampled soil sequences. Then I do the same for the Fondi plain.

2.1.1 Agro Pontino

The Agro Pontino consists of an elevated complex of Middle to Late Pleistocene terraces along the coast and a low-lying graben situated inland. Holocene sediments cover the Late Pleistocene Borgo Hermada marine terrace and fill old fluvial incisions. In the Middle Holocene, a lagoon system formed that was later cut off from the sea by the formation of beach ridges and the continued development of a fluvial fan formed by the Amaseno River. Lakes and marshes developed, and



there the deposited Avellino tephra is in places well preserved. From the Early Iron Age onwards, colluvial fans covered the Holocene and Pleistocene lagoon deposits in the north-western part of the Agro Pontino (Van Gorp & Sevink 2019). For an extensive description of the modern vegetation in the area, see Doorenbosch and Field (2019). Three locations (Frasso, Borgo Hermada 362 and Borgo Hermada 192) were chosen for sampling on the Agro Pontino plain, to complement the profiles from the sampling locations known as Ricci and Mezzaluna that have already been investigated and published by Bakels et al. (2015) (Fig. 3).

2.1.1.1 Frasso (test pit)

Frasso is located in a gully in the south-western part of the Agro Pontino. The upper part of the gully is

filled with peat that the landowner had recently covered with reddish brown soil. In the peat, at a depth of around 60 cm, a 2 cm thick tephra layer is present. A pit was dug into the top of the gully infill (Fig. 4). A 50 cm vertical monolith was extracted from profile Frasso 500 for pollen analysis. A horizontal monolith was extracted for plant macro-fossil analysis. ¹⁴C dates were obtained from samples taken at various depths from the horizontal, plant macro-fossil monolith. From the vertical monolith, 24 subsamples of 2 cm³ were taken at 1 cm intervals, from 27 cm to 49 cm depth below the surface. The extraction and picking of all of the samples discussed in this paper follow the same procedure, as follows: For the extraction of pollen, the samples were treated with 10% KOH, 37% HCl, Bromoform/ethanol (specific gravity 2.0) and acetolysis. Tablets containing a known number of *Lycopodium* spores were



2.1.1.2 Borgo Hermada 362 (test pit)

The sampling location Borgo Hermada 362 is situated in the Agro Pontino, south of Frasso. It consists of a gully filled with peat, resting on top of a lagoon clay. A tephra layer was deposited at the transition between the lagoon clay and the peat, at a depth of around 60 cm below the surface. Based on its mineralogical and granulometric characteristics, Sevink *et al.* (2021) concluded that this tephra layer originated from the Avellino eruption. On top of the tephra, a layer of peat was present, with a thickness of about 25 cm. A pit was dug, and three vertical monoliths covering 56.5 cm were taken to be used for pollen analysis (Fig. 5a, b). One monolith was cut up into

Fig. 4. Photo of the Frasso pollen core, divided into slices of 1 cm.



Fig. 5a. Photo of the test pit taken at Borgo Hermada 362.

slices of 1 cm thickness, and eight slices were selected for pollen preparation. A ^{14}C date was obtained from a sample taken at only a few centimetres above the tephra layer.

2.1.1.3 Borgo Hermada 192 (core)

East of BH362, a core was taken from a gully filled with lagoonal clay, gyttja and peat. At this location, known as Borgo Hermada 192, a tephra layer present between the lagoon clay and the gyttja, at a depth of about 65 cm below surface was interpreted as Avellino tephra (Sevink *et al.* 2021). Sediment samples from an 85 cm long profile were taken using an auger (Fig. 6). This profile was cut up in slices of 1 cm thickness. Subsequently, eight 2 cm³ slices were analysed for pollen.



Fig. 5b. Photo the two monoliths taken at Borgo Hermada 362.



Fig. 6. Photo of core Borgo Hermada 192 in the field, showing the tephra layer.

2.1.2 Fondi basin

The Fondi basin is a tectonic basin bordered by steep limestone hills and the Tyrrhenian Sea. In the coastal area of the basin, Pleistocene and Holocene beach ridges enclose a lagoon largely filled in with peat and lagoonal clay. Inland, a complex of Late Pleistocene beach ridges and lagoons and an intricate system of fluvial incisions formed, which are now partially filled in with Holocene sediments. Roman and post-Roman colluvial deposits buried most of the inland lagoon (Sevink 1984; Feiken 2014; Bakels *et al.* 2015; Van Gorp & Sevink 2019). Three locations were selected for investigation: Femmina Morta 197, Tumolillo 2 and Fondi inland 122A.

2.1.2.1 Femmina Morta 197 (test pit)

For a full description of the site, core, methodology and results of the Femmina Morta 197 core, I refer the reader to Doorenbosch and Field (2019). In this paper, I will limit myself to a summary of the archaeobotanical results presented in that paper and will add additional dating evidence. The core appeared to have two tephra layers, of which the upper layer is the Avellino tephra and the lower tephra results from the Astroni 6 eruption of the Campi Flegrei (Sevink *et al.* 2021) (Fig. 7). The dates given in Doorenbosch and Field (2019) indicate that peat accumulation took place from the EBA into the Middle Bronze Age. New radiocarbon dates of peats above and below the AV tephra layer from Femmina Morta 197 provide a more precise chronology.

Fig. 7. Photo of core Femmina Morta 197 in the field, showing the two tephra layers.

Fig. 8. (right) Photo of core Fondi inland 122A in the field.



Fig. 9. Photo of core Tumolillo 2 in the field, showing the two tephra layers.



2.1.2.2 Fondi inland 122A (core)

To investigate the inland part of the Fondi basin, core 122A was collected. At this location, about 1 m of peat had been deposited on top of a calcareous mud. Within the peat, at a depth of around 81 cm below the surface is a 2 cm thick layer of tephra (Fig. 8). Dates and tephra characterization have confirmed this to be the AV tephra layer (Sevink *et al.* 2021; Van Gorp & Sevink in press). The core, with a length of 43 cm (63–106 cm below surface) was cut up into 1 cm thick slices. Subsequently, 16 subsamples of 2 cm³ were studied for pollen. Preparation revealed that pollen was absent from the tephra layer sample.

2.1.2.3 Tumolillo 2 (core)

South-east of Femmina Morta, situated close to the Terracina beach ridges along the coast, two tephra layers were deposited in peat (Fig. 9). Tephra characterisation and radiocarbon dates revealed that the upper tephra layer originates from the Avellino eruption and the lower tephra from the Astroni 6 eruption (Sevink *et al.* 2021; Van Gorp & Sevink in press). A sediment sequence 45 cm in length (75–120 cm below surface) was retrieved with an auger. After 1 cm thick slices of the sediment sequence were made, subsamples of 2 cm³ were taken for palynological analysis.

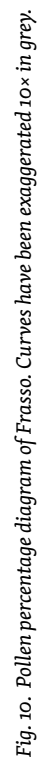
3. Results

3.1 Agro Pontino

3.1.1 Frasso

The results are shown in Fig. 10 and 11. The pollen diagram (Fig. 10) can be divided into two local pollen assemblage zones separated by a tephra layer (Zone 1a).

Zone 1 shows the presence of deciduous oak forest in the area, represented by high percentages of pollen of the *Quercus robur-pubescentis*-type. Deciduous oak forest was most likely present on the drier, inland parts of the Agro Pontino. Today this forest is only preserved in the national parks (e.g. Parco Nazionale del Circeo; Anzalone *et al.* 1997), but it was more widespread in the area in earlier times (Sadori *et al.* 2015). Not only species such as *Q. pubescens*, *Quercus frainetto* and *Q. robur* (represented in the *Q. robur-pubescentis*-type), but also *Quercus cerris*, *Carpinus betulus*, *Fraxinus angustifolia* (*Fraxinus excelsior*-type) and *Carpinus orientalis* (represented by *Ostrya*-type) form part of the deciduous oak forest. Another type of deciduous forest, composed of such species as *Q. robur*, *Q. pubescens*, *Q. cerris*, *Fraxinus ornus*, *Ostrya carpinifolia*, was probably present on the lower slopes of the mountains surrounding the area,



Frasso**Lazio, Italy**

Analysis: Rory Granleese

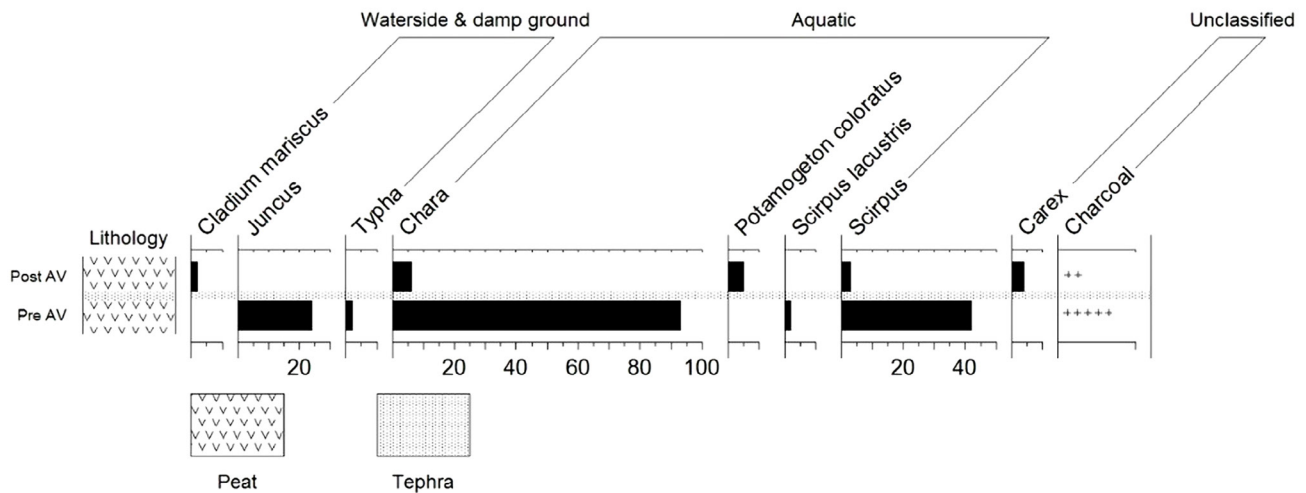


Fig. 11. Macro-fossil diagram of Frasso (analysis Rory Granleese, University of Leiden).

as these species are found today in the Parco Regionale dei Monti Aurunci (Bianco & Ciccarese 2013) and the National Park of Abruzzo (Conti & Bartolucci 2015). *Quercus ilex*-type and *Q. cerris*-type are also well represented in Zone 1. *Q. cerris*-type includes the deciduous oak *Q. cerris* as well as the evergreen oak *Quercus suber*. While *Q. cerris* was most likely part of the deciduous forest types described above, *Q. suber* could have grown on soils that lacked calcium carbonate. *Q. ilex*-type comprises the evergreen oak species *Q. ilex* and *Quercus coccifera*. These were most likely present on lower elevations throughout the area, together with maquis-type vegetation, represented in the diagram by *Phillyrea*, *Olea europaea*, *Pistacia* and *Ericaceae*. Pollen of *Fagus* most likely originated from higher up in the mountains surrounding the plain. Zone 2 shows a regional vegetation that resembles that described for Zone 1. Pollen of *Q. ilex*-type show a slight decrease, possibly caused by changes in precipitation (e.g. drought stress).

In both zones, a hydrosere succession from a swamp vegetation to alder carr is evident in the local environment. Zone 1 starts with the presence of few aquatic taxa, such as *Lemna* and *Nymphaea*, which decrease quickly as swamp vegetation including *Sparganium*, *Poaceae*, *Carex* and/or *Cladium* and other *Cyperaceae* taxa shows an expansion. Succession of the vegetation continues after the AV tephra deposition in Zone 2 and does not appear to have been affected by the ash fallout. Zone 2 starts with an expansion of ferns that produce monolete psilate spores and is followed by the development of an alder carr composed mostly of *Alnus* and *Salix*. A hydrosere succession took place in the area, possibly enhanced by slight drying out of the area in the period after a decrease in relative sea level (recorded by

van Gorp *et al.* 2019). The change in hydrological conditions could also be the result of a change in regional climate, as *Q. ilex* percentages drop simultaneously. It should be noted that some open water must still have been present at the sampling location because of the presence of *Potamogeton coloratus* in the plant macro-fossil assemblage from this level.

Hardly any charcoal is present in the pollen assemblage in samples from the period preceding the tephra deposition. Charcoal shows a peak after the tephra deposition. This seems to be contradicted by the amounts of charcoal present in the plant macro-fossil samples, where numbers of charcoal particles are higher before than after the tephra deposition. Similar results were found in the FM197 section. This contradiction may be possibly caused by taphonomic processes operating differently on various charcoal size classes (Doorenbosch & Field 2019). Below the tephra layer, larger particles of charcoal were present in higher concentrations in the plant macro-fossil diagram (Fig. 11), while smaller charcoal particles were present in low concentrations in the pollen diagram (Fig. 10). This could indicate local burning of the vegetation. Above the tephra layer, the concentration of larger charcoal fragments is lower, possibly due to a decrease in local burning. The smaller charcoal particles present in the pollen diagram could indicate some regional burning in the period after the tephra deposition. These smaller particles arrive at the site after being transported in the atmosphere. It is difficult to determine whether the burning was the result of natural causes or of anthropogenic activity. Since there is no other evidence for human activity in the area, I favour a natural cause.

BH 192

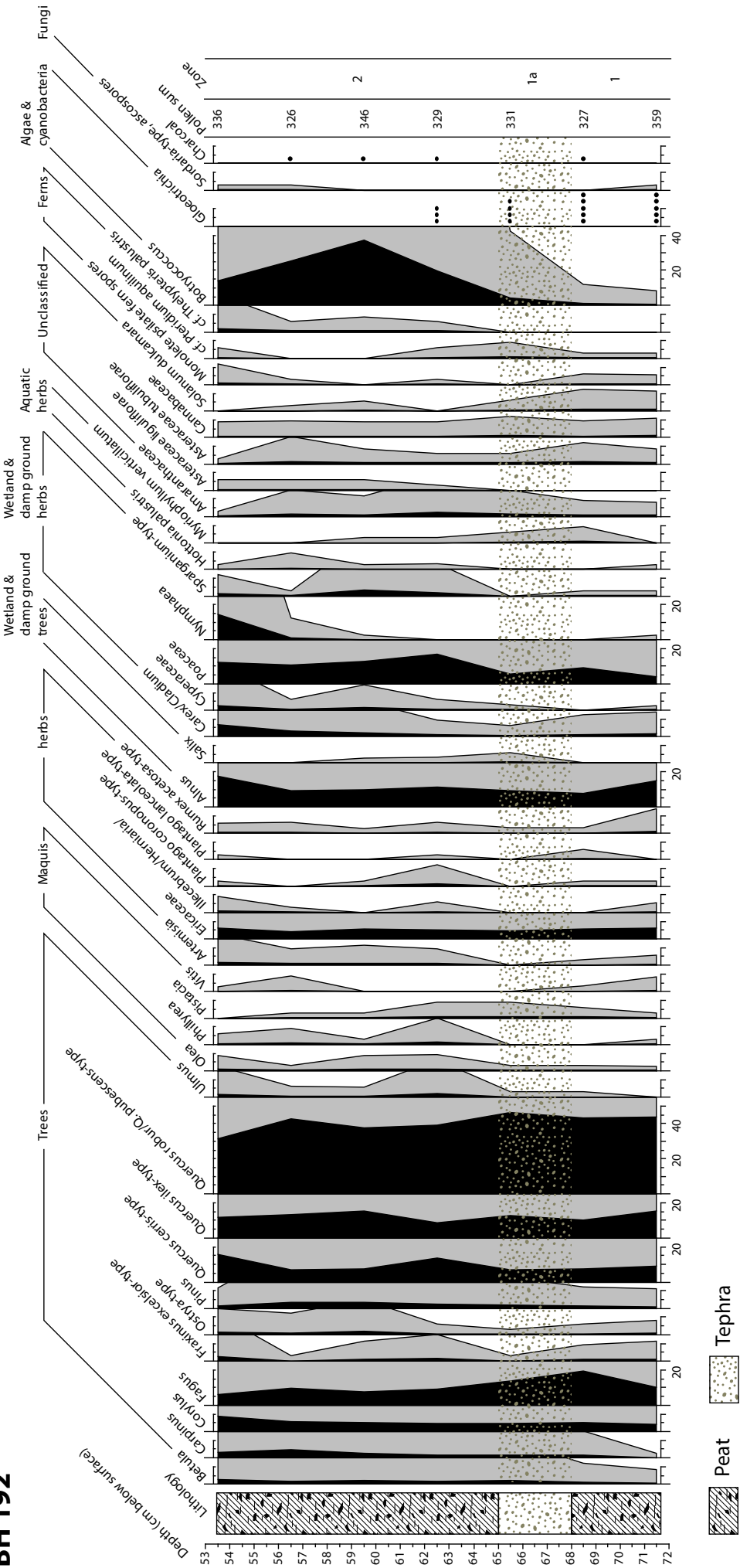


Fig. 12. Pollen percentage diagram of Borgo Hermada 192. Curves have been exaggerated 10× in grey.

BH 362 **Agro Pontino, Italy**

Analysis: M. Doorenbosch

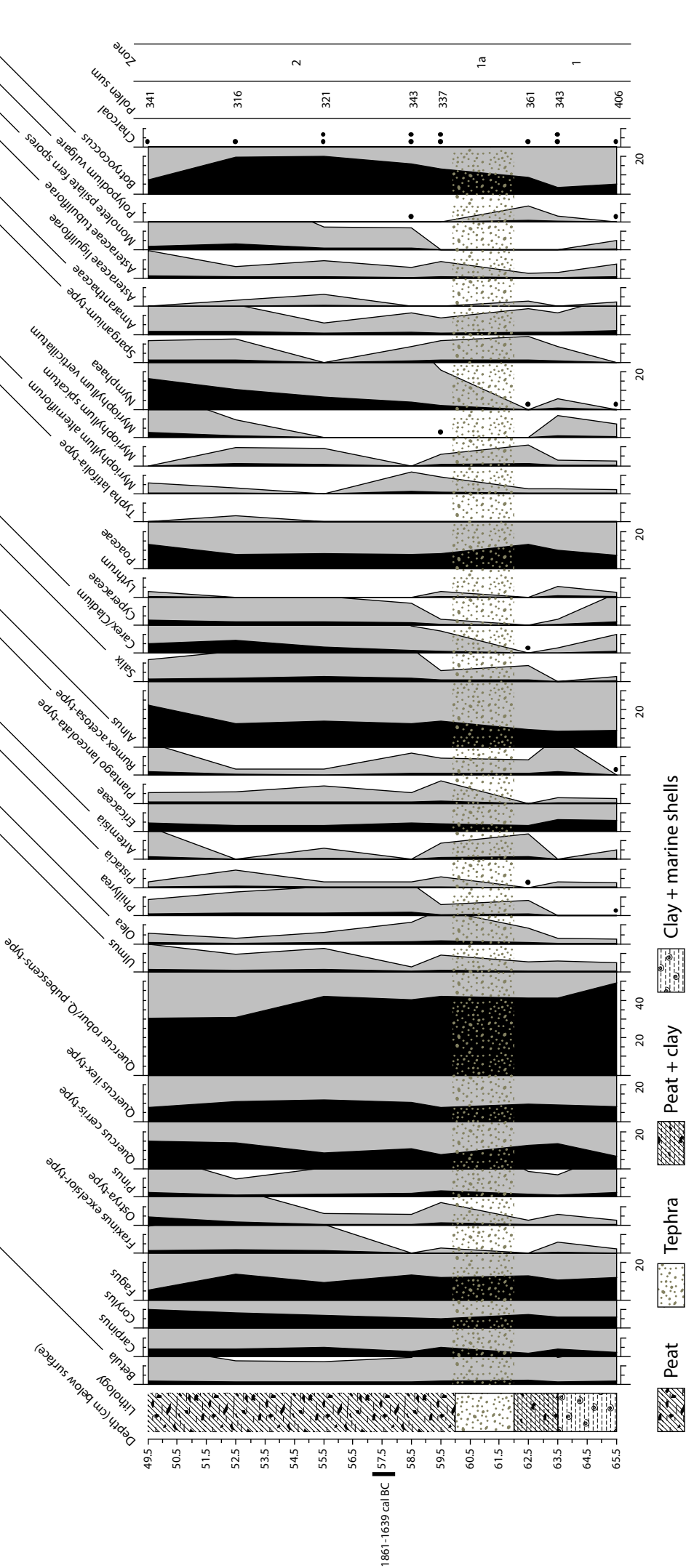


Fig. 13. Pollen percentage diagram of Borgo Hermada 362. Curves have been exaggerated 10× in grey.

Femmina Morta 197, Fondi, Italy

Analysis: M. Doorenbosch

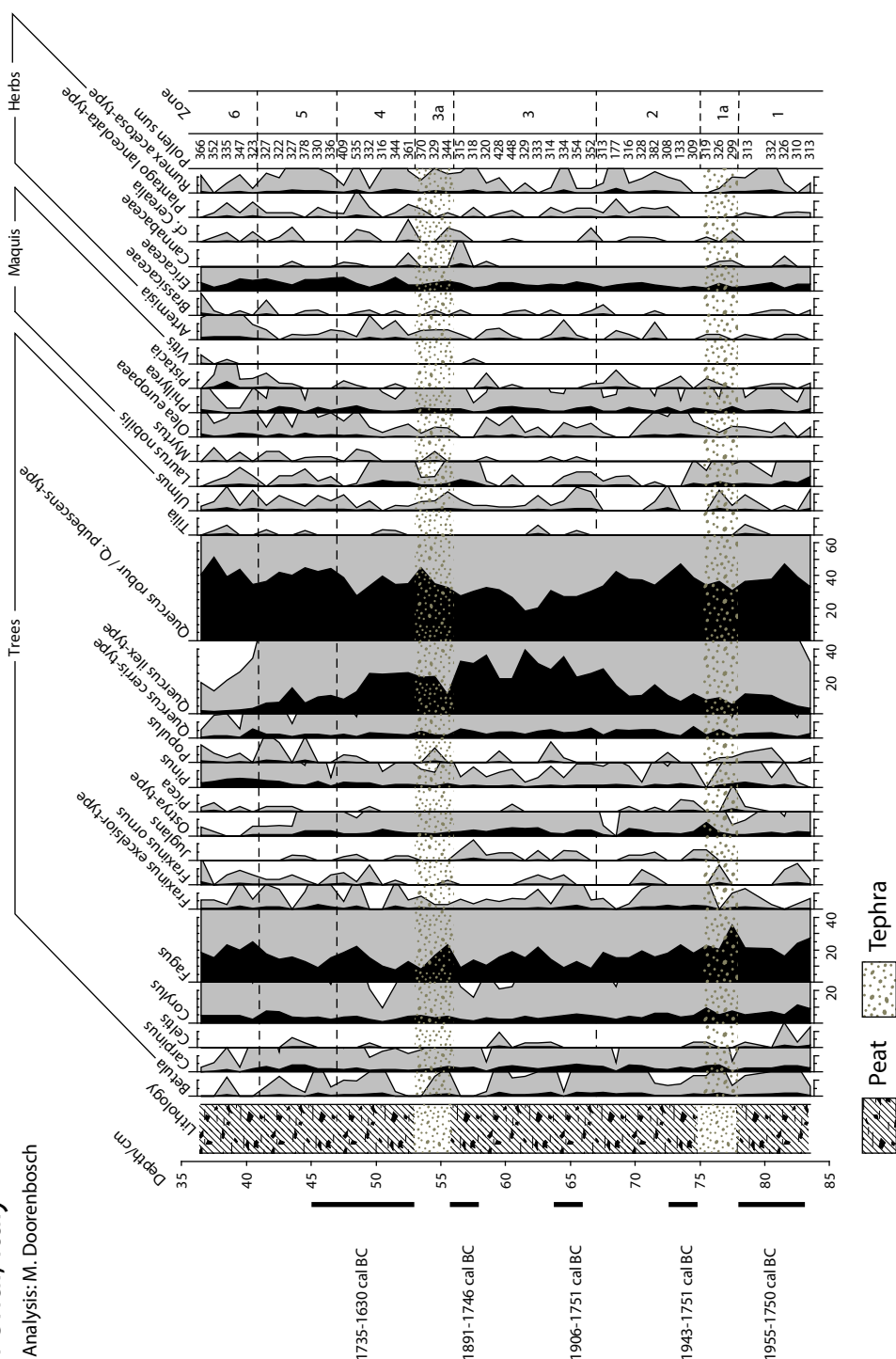


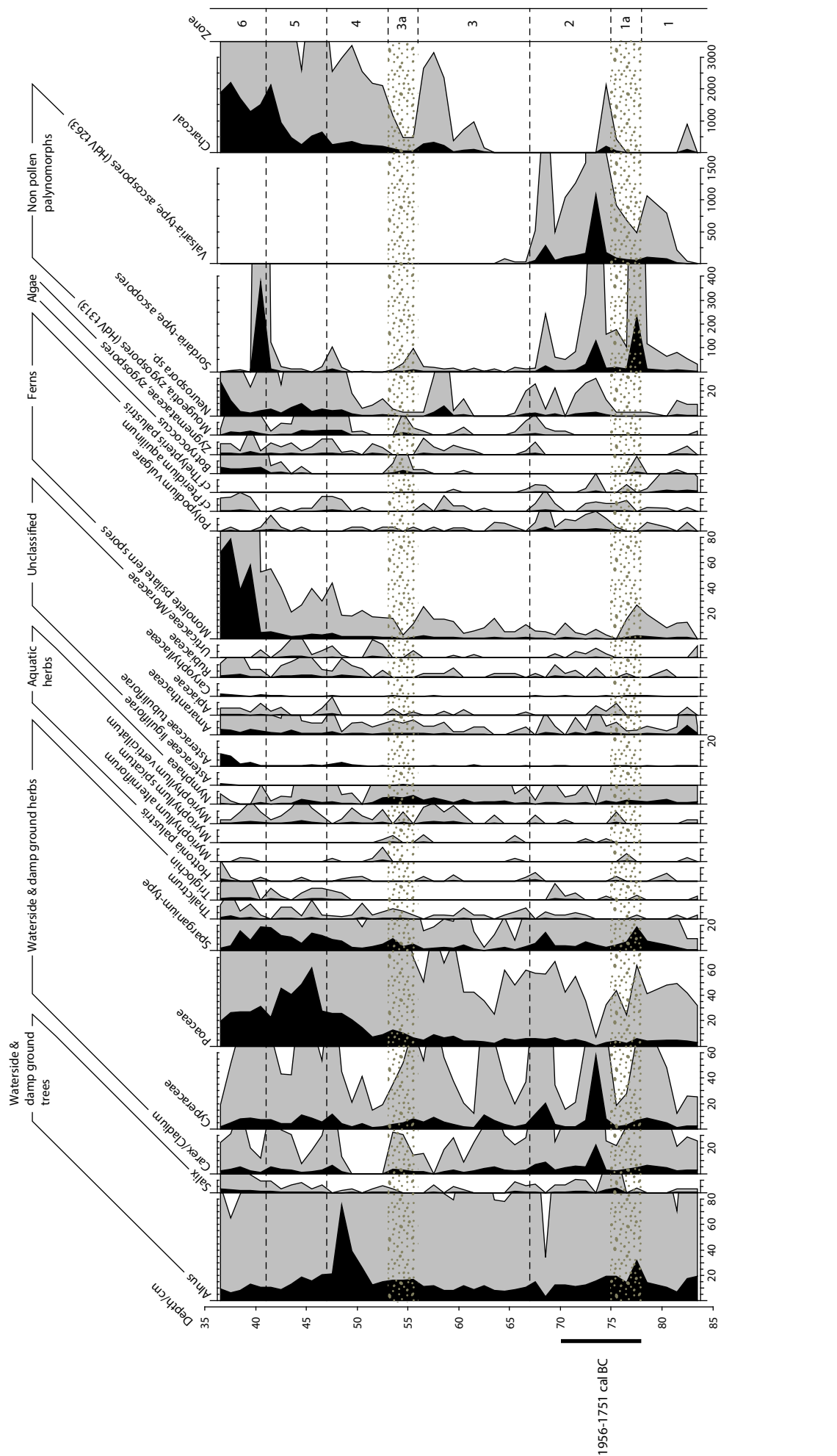
Fig. 14. (also next page) Pollen percentage diagram of Femmina Morta 197. Curves have been exaggerated 10× in grey.

3.1.2 Borgo Hermada 192

Fig. 12 presents the palynological results of analyses of BH192 sediments. The diagram mostly shows the vegetation development after the tephra deposition. The pollen data indicate a stable landscape, comparable to that described above from Frasso, with vegetation dominated by deciduous oak and evergreen oak forest. Towards the end of Zone 2, *Q. ilex*-type pollen begins to decrease, a trend that also had been observed at Frasso. However, the decrease at BH192 is minimal. Possibly it reflects the

start of a drier climatic period (Drescher-Schneider *et al.* 2007; Di Rita & Magri 2009; Di Rita *et al.* 2018).

The local vegetation component represented in the pollen assemblages shows a wetland vegetation with alder carr (*Alnus*) and *Poaceae*. Also present in the local vegetation were *Carex/Cladium* and *Sparganium*. In Zone 2, *Poaceae* and *Sparganium* increase, followed, at the end of Zone 2, by *Carex/Cladium*, *Nymphaea* and, possibly, *Alnus*. Zone 2 shows an increase in *Botryococcus*, a microalga that prefers shallow, freshwater habitats but is also known to inhabit a wide range of environments varying



**Femmina Morta 197,
Lazio, Italy**
Analysis: M.H. Field

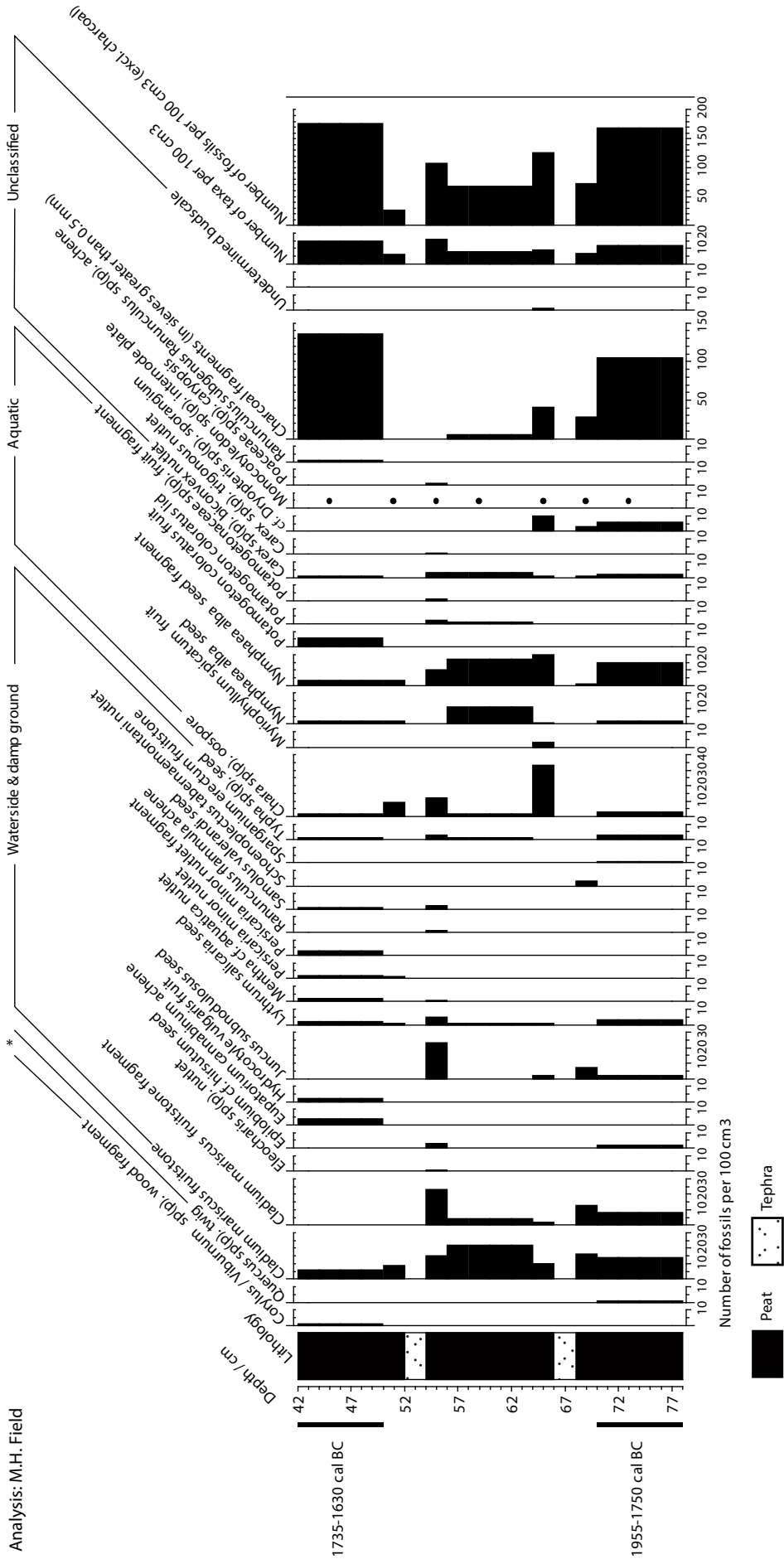


Fig. 15. Macro-fossil diagram of Femmina Morta 197 (analysis Mike Field, University of Leiden).

from fresh to saline water. Sometimes it can also survive periods of drought (Clausing 1999; Demetrescu 1999). Throughout the entire profile, only low concentrations of charcoal were present.

3.1.3 Borgo Hermada 362

The pollen diagram from BH362 is very similar to that of BH192, in terms of both the regional and the local signal it contains (Fig. 13).

3.2 Fondi basin

3.2.1 Femmina Morta 197

Two tephra layers were discovered in the FM197 profile. The palaeobotanical investigation showed that neither of the tephra fallout events affected either the local or the regional vegetation (Fig. 14, 15). At the point of sampling, a low-energy, shallow lacustrine basin with aquatic plants existed, surrounded by a reed swamp. The regional vegetation was composed of mixed deciduous oak forest with evergreen elements. In the period before the Astroni 6, the evergreen forest started to expand, while deciduous forest cover apparently decreased. This trend continues after the eruption and comes to an end before the deposition of the AV tephra. It is possible that the 4.2 ka BP climatic event, which took place shortly after the Astroni 6 eruption (Smith *et al.* 2011), is recorded in the diagram. This event was characterised by drier conditions in the central and southern parts of Italy (Di Rita & Magri 2009, 2019; Bini *et al.* 2019), mostly affecting the evergreen forest, since *Q. ilex* is sensitive to drought (Barbero *et al.* 1992). Recovery is shown in Zone 2 and continues in Zone 3. The decrease in evergreen forest, recorded in the period after the AV eruption and associated tephra fallout (end of Zone 4, Zone 5 and Zone 6), may be linked to changes in climate as well, rather than to human activity in the area (Doorenbosch & Field 2019).

3.2.2 Tumolillo 2

Two tephra layers were encountered in the sequence of peat from Tumolillo 2. The upper tephra is probably the result of the Avellino eruption, whereas the lower tephra probably derives from the Astroni 6 eruption (Sevink *et al.* 2001).

The pollen diagram of Tumolillo 2 can be divided into five local pollen assemblage zones (Fig. 16). Zone 1, below the Astroni tephra, shows the presence of swamp vegetation, with an increase in *Carex/Cladium* pollen and in spores of *Osmunda regalis* and other ferns (that produce monolet psilate spores). An alder carr is indicated by *Alnus* pollen and increasing numbers of *Salix* pollen. *Hottonia palustris* forms part of the swamp

vegetation. The presence of *Lemna* suggests the water-body was still or slow moving and contained fresh water. In Zones 1a and 2, there is a temporary dip in the percentages of *O. regalis* and monolet psilate fern spores and *Carex/Cladium* pollen, possibly caused by the deposition of tephra affecting the herbal vegetation in the swamp. Trees present in the local environment seem unaffected, and *Alnus* and *Salix* show an increase. At the end of Zone 2, the percentages of *Alnus* and *Salix*, as well as *O. regalis*, decrease. Although monolet psilate fern spores first show an increase at the end of Zone 2, they also decrease in Zone 3. *Alnus*, *Salix* and *O. regalis* remain low, while *Carex/Cladium* and other Cyperaceae increase as well as *Sparganium*. Towards the end of Zone 3, *Carex/Cladium* start to decrease. Zone 4 shows the start of an expansion of the alder carr, with an increase in the percentage of *Alnus* pollen that continues after the deposition of the Avellino tephra. This is followed by a proportional increase in ferns that produce monolet psilate spores and in *Salix* pollen. Fluctuations in local vegetation point to local changes in the water table. *Cladium mariscus*, for example, is sensitive to changes in hydrological conditions (Theocharopoulos *et al.* 2006). Similar fluctuations have been recorded in the coastal pollen diagram from Fogliano (Van Joolen 2003).

The increase in *Alnus* can also be noted in the FM197 pollen diagram (Doorenbosch & Field 2019), although after the Avellino tephra was deposited, a decrease sets in rather quickly. *Salix* shows a minor increase as well. The increase in monolet psilate spore-producing ferns is not seen in the FM197 pollen diagram until sometime after the AV eruption, at the top of the diagram.

The regional pollen assemblage shows a relatively stable deciduous oak forest (*Q. robur-pubescens*-type), with evergreen elements (*Q. ilex*-type). Pollen of *Myrtus*, *Phillyrea*, *Pistacia* and *Vitis* probably derived from maquis vegetation that was in all probability present on the hill slopes together with *Q. ilex*. *Vitis sylvestris* is a damp valley species, while *V. vinifera* is cultivated. Therefore the *Vitis* in the pollen assemblage probably represents human activity on the hill slopes. Temperate forest is represented by *Fagus* pollen, most likely originating from the mountainous areas surrounding the Fondi basin. It is possible that the end of the 4.2 ka BP climatic event is recorded in Zone 1 of the pollen diagram. Low percentages of, for example, *Q. ilex*-type and *Q. cerris*-type could point to a drop in forest cover due to (climatic) aridification of the area. *Q. ilex* shows an increase after the lower tephra deposition in Zones 2 and 3. *Q. robur-pubescens*-type decreases slightly in Zones 2 and 3. The increase in *Q. ilex*-type comes to an end in Zone 3 and percentages drop further in Zone 4, before the AV eruption, staying low after the eruption event in Zone 5. The trend of a decrease in the evergreen forest can also be seen in FM197, where percentages drop after the deposition of the AV tephra, as well as in the Agro Pontino

Tumolillo 2 Fondi basin, Italy

Analysis: M. Doorenbosch

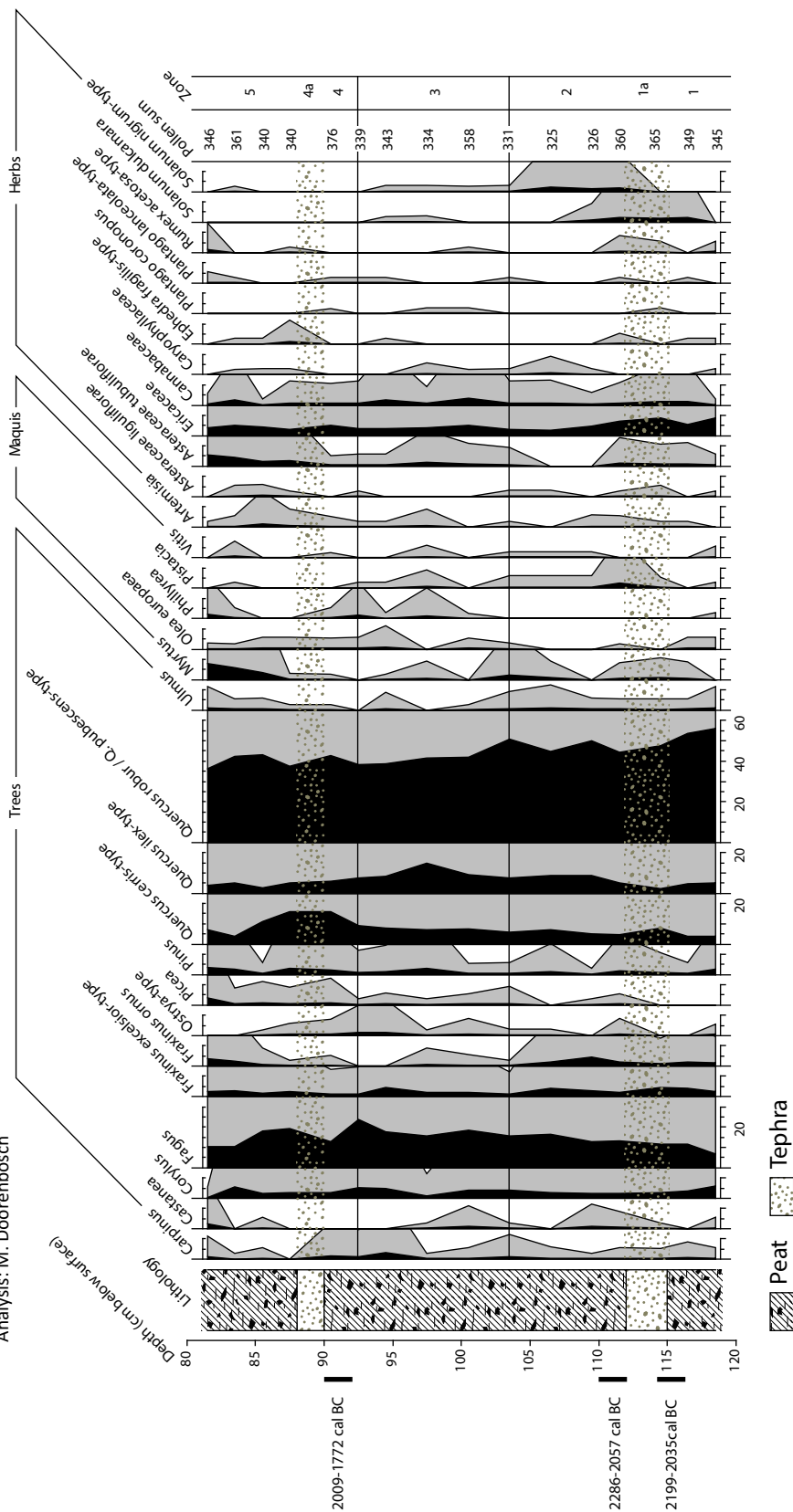
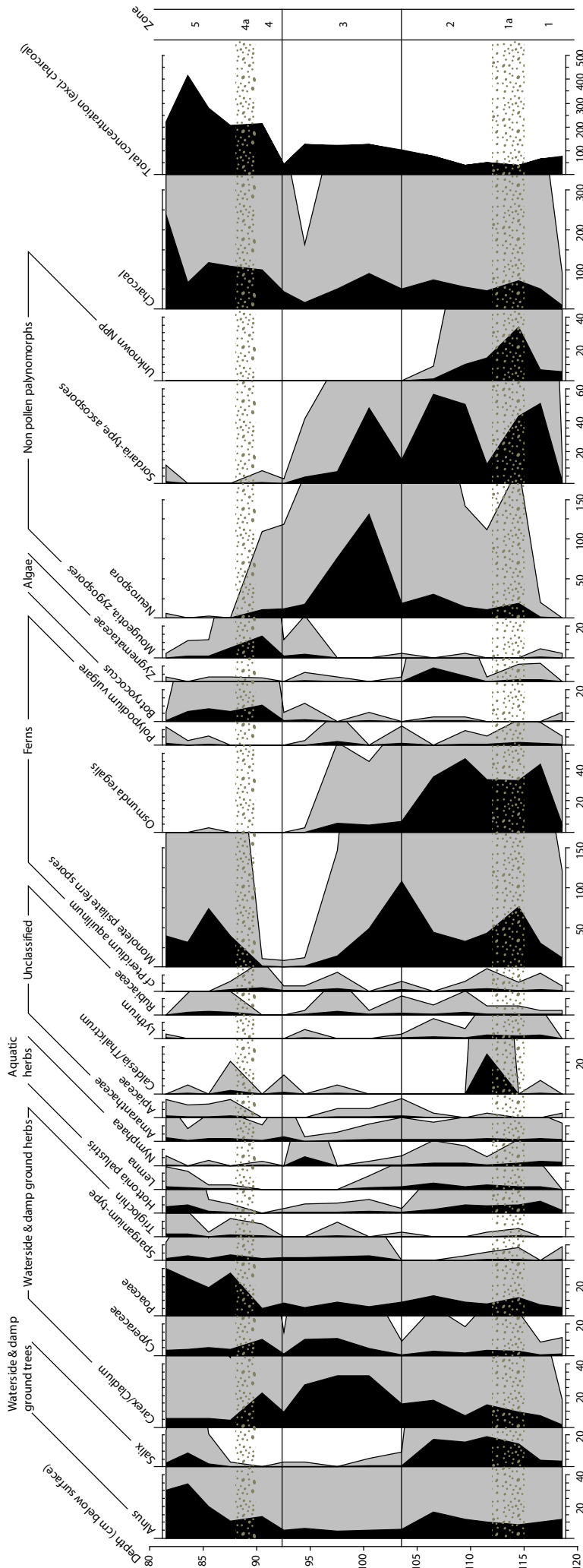


Fig. 16. (also next page) Pollen percentage diagram of Tumolillo 2. Curves have been exaggerated 10× in grey.

pollen records. *Q. cerris* shows a slight increase before the lower tephra deposition and remains stable after this deposition. An increase takes place again before the Avellino tephra deposition, reaching its maximum just before or around the eruption. After the Avellino deposition, percentages seem to decrease again to numbers comparable to before the second increase (Zones 1–3). In general, percentages of *Q. cerris* seem to be slightly

higher at TUM2 than at FM197 (4–10% versus 1–7%). Temperate forest pollen (*Fagus*) was relatively stable. A slight increase started before the lower tephra deposition and continued very slowly until a slight decrease set in before the upper tephra had deposited. The decrease continued after the upper tephra deposition. The continuous presence of *Fagus* is comparable to Femmina Morta, including a temporary decrease after the Avellino



eruption. The two locations are located closely to each other, so they have a similar pollen source for extra-local and longer distance pollen. In the case of *Fagus*, this source is most likely the higher elevations on the slopes surrounding the Fondi basin. Charcoal is present in all spectra and any increase seems not to relate to the tephra deposition events. The presence of micro-charcoal in the pollen spectra indicates regional burning. However, this is contradicted by the (near) absence of micro-charcoal in the nearby profile of FM197 around the Avellino eruption. The presence of larger charcoal particles in FM197 suggests that only local burning of vegetation had taken place.

3.2.3 Fondi inland 122A

This site is more inland compared with Femmina Morta and Tumolillo, being approximately 4 km from the coast, about 2 km east of Fondi Lake, and roughly 11 km west of Monti Aurunci. Therefore, the sea has less of an impact.

The pollen diagram of Fondi inland 122A (Fig. 17) resembles the pollen diagrams of Tumolillo 2 and Femmina Morta 197. A very stable deciduous oak forest vegetation is shown, with consistent percentages of *Q. robur-pubescens*-type. Only towards the end of Zone 2 does a slight decrease occur, which can also be observed in the diagrams of Tumolillo 2 and Femmina Morta 197 in the period after the deposition of the Avellino tephra.

The local vegetation is a marsh vegetation with *Carex/Cladium* and other Cyperaceae, *Sparganium*, *Nymphaea* and Poaceae. Nearby, an alder carr with *Alnus* and *Salix* is present. The Cannabaceae species present probably formed part of the local vegetation. Zone 2 shows a minor increase in *Alnus*, *Salix* and Poaceae and a slight decrease in *Carex/Cladium*. This could be the start of a hydrosere succession. However, the sequence sampled does not continue long enough to establish this with certainty. Only few charcoal particles are present throughout the profile, with the highest concentrations present before the Avellino tephra fallout. Little charcoal is recorded, with most charcoal particles present before the tephra fallout. It should

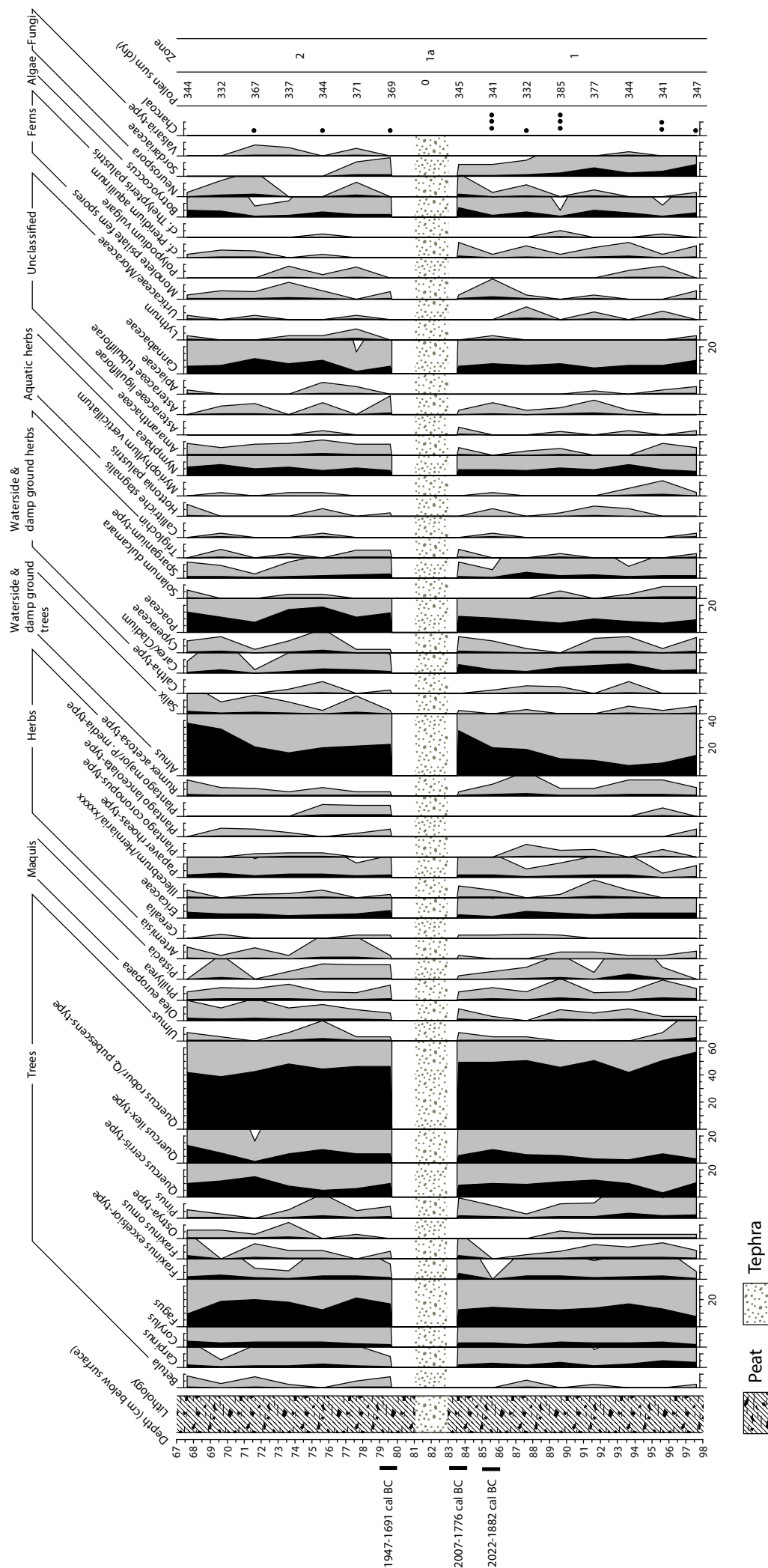


Fig. 17. Pollen percentage diagram of Fondi inland 122A. Curves have been exaggerated 10× in grey.

be noted that the tephra layer was very clean and that pollen and spores were absent.

4. Discussion

The palaeobotanical investigation of samples from stratified soil sequences from pits and cores in the Agro Pontino and Fondi basins containing the Avellino tephra allowed a detailed reconstruction of the vegetation of the landscape in the Bronze Age before and after the Avellino Event. Within the framework of the Avellino Event Project, several new locations were investigated, to complement those investigated during the work by Bakels *et al.* (2015). Besides tephra from the Somma-Vesuvius complex, we also found tephtras from the Astroni volcanic complex. Based on the palaeobotanical analysis of a stratified soil sequence from a test pit dug at the location of Femmina Morta in the Fondi basin, Doorenbosch and Field (2019) noted that there is no evidence to suggest that the Avellino ash had a serious impact on the local vegetation. They also noted that anthropogenic impact in the period seemed low. These insights, which had already gained at the outset of the project, were corroborated by the results obtained during the project and presented in full in this paper.

The impacts of tephra fallout have been described by Payne *et al.* (2013); these can include damaging of plant tissues, the inhibition of photosynthesis and vulnerability to disease. One would expect such impacts to cause changes in vegetation composition. In the data presented in this paper, no such impacts have been observed in the palaeobotanical records covering the period following the Avellino ash fall.

The palaeobotanical results presented in this paper are not indicative of any serious pressure on the natural environment. The area therefore seems not to have been densely populated. This finding is in line with the archaeological evidence (Kamermans 1993; Van Joolen 2003; Alessandri 2009, 2013). In fact, archaeological fieldwork undertaken as part of the Avellino Even Project added only few new archaeological traces to the existing body of evidence, implying that the project's central hypothesis of an in-migration of people from Campania at the time of the Avellino eruption must be rejected. Instead, the vegetation reconstructions suggest a relatively stable landscape. Temperate forest is represented by *Fagus*, probably originating from higher elevations in the surroundings of the Agro Pontino and Fondi basin. Mixed deciduous oak forest composed of several deciduous *Quercus* species as well as *F. ornus*, *F. excelsior*, *O. carpinifolia* and *C. orientalis* existed on lower elevation slopes surrounding both basins and/or on the drier, inland parts of the lowlands. Evergreen forest with *Q. ilex* and *Q. coccifera* was present at lower elevations, together with maquis vegetation. Human impact can be indicated in the form of cultivated trees, such as *Juglans*, *Castanea* and

Olea (Mercuri *et al.* 2013). This also holds for the increase in cultivated herbs, such as cereals and legumes, and accompanying arable weed herbs *Plantago lanceolata*, *Rumex acetosa* and *Urticaceae* (Behre 1981, 1982; Sadori *et al.* 2010; Brun 2011). The fact that these anthropogenic indicators are hardly present in the palaeobotanical records of the investigated region supports the idea that population was low in the Agro Pontino and Fondi basins in the EBA. The vegetation record from the area does not show significant signs of human disturbance. In the north-western part of the Agro Pontino, some human disturbance may be visible in the form of a sudden decrease in alder carr in the pollen diagrams from Ricci and Mezzaluna (Bakels *et al.* 2013). Such changes in vegetation have not been recorded elsewhere in the Agro Pontino or in the Fondi basin. This indicates that human occupation in the area was local and limited in the period before the Avellino eruption.

The 4.2 ka BP climatic event caused variation in the evergreen and mixed oak forest cover. Evergreen forest cover decreased because of drought, and the recovery from this drought is possibly visible in the pollen diagrams from Ricci (Bakels *et al.* 2015), as well as in those from Tumolillo 2 and Femmina Morta 197. Local fluctuations in vegetation in the period before the deposition of the AV tephra in, for example Tumolillo 2 and Frasso 500, seem to be site specific and point to changes in local hydrological conditions, leading to vegetational succession into an alder carr. These changes in vegetation are not likely to have been caused by human activity. In addition, after the Avellino eruption, there is no evidence of increasing human disturbance due to either the growth of a resident population or the arrival of migrants. A decrease in evergreen forest recorded above the Avellino tephra layer in the diagrams of Frasso, Femmina Morta 197 and Borgo Hermada were most likely the result of changes in climate, rather than human impact. Despite the proximity of these locations to the sea, their pollen records, especially those of the Fondi basin, show mainly evidence of fresh water. No halophytic taxa have been encountered in the macrofossil assemblage, and *Triglochin* is the only indication of brackish conditions, recorded in low percentages in the pollen records of the Fondi basin.

5. Conclusion

From the vegetation reconstruction based on palaeobotanical investigations conducted in the Agro Pontino and the Fondi basin, it appears that the Bronze Age landscape was a relatively stable landscape, consisting of a mosaic of vegetation communities that were not significantly affected by human activity. Changes in regional deciduous and evergreen oak forest were most likely caused by changes in climate. Variations in local vegetation can be explained by changes in local hydrological

conditions. None of the three tephra fallout events that have been registered in the investigated sediment cores seem to have greatly affected either the regional or the local vegetation.

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