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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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# The Avellino Event

## Cultural and Demographic Effects of the Great Bronze Age Eruption of Mount Vesuvius. Overview of main project results, publications and valorisation activities

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**Abstract:** Between 2015 and 2019, a team of archaeologists, palaeobotanists and geologists from the Universities of Groningen, Amsterdam and Leiden looked into the distal effects of a powerful eruption of the Somma–Vesuvius volcano in Campania on the former wetlands of the Agro Pontino and Fondi coastal plains in Central Tyrrhenian Italy. These wetlands are located c. 60 km south of Rome and between 90 and 140 km north-west of Mount Vesuvius. The ‘Avellino’ eruption took place during an advanced stage of the Early Bronze Age and was radiocarbon dated around 1900 BCE. This article reports on the results of the research programme ‘The Avellino Event: Cultural and Demographic Effects of the Great Bronze Age Eruption of Mount Vesuvius’, funded by the Dutch Research Council. The team’s main hypothesis, that people living in the surroundings of Mount Vesuvius in the Early Bronze Age who had time to escape the proximal effects of the eruption – pyroclastic flows and heavy ash falls – fled to the relative safety of nearby coastal areas to build a temporary or permanent new existence, was disproved by field evidence early on. No major environmental and archaeological impacts were evident in the archaeological and environmental record of the study area around the date of the eruption. Nonetheless, the research resulted in a significant increase in geological and palaeobotanical data, which has proved extremely useful for the reconstruction of the *longue durée* of human–landscape interactions. The Avellino tephra was a most reliable chronological horizon in this reconstruction contributing to the overall objectives of the long-running Pontine Region Project of the University of Groningen. This contribution contains an overview of the main results of the Avellino Event Project, including an overview of scientific publications, valorisation output, and a brief discussion of some remarkable spin-off projects.

**Keywords:** Central Italy, Pontine plain, Fondi Basin, Bronze Age, Distal effects of volcanic eruptions, Bronze Age eruption of Somma–Vesuvius, Wetland archaeology, Palaeoenvironmental reconstruction

### 1. Introduction

Between June 2015 and June 2019, researchers of the Groningen Institute of Archaeology (GIA) of the University of Groningen; the Faculty of Archaeology of the University of Leiden; and the Institute for Biodiversity and Ecosystem Dynamics of the University of Amsterdam (IBED) carried out the research programme *The Avellino Event: Cultural and Demographic*

*Effects of the Great Bronze Age Eruption of Mount Vesuvius*, funded by the Dutch Research Council.<sup>1</sup> A multidisciplinary team composed of archaeologists, palaeobotanists and geologists looked into the distal effects of the powerful eruption of the Somma–Vesuvius volcano around 1900 calBC, called the Avellino Event, on the former wetlands of the Agro Pontino and Fondi basin coastal

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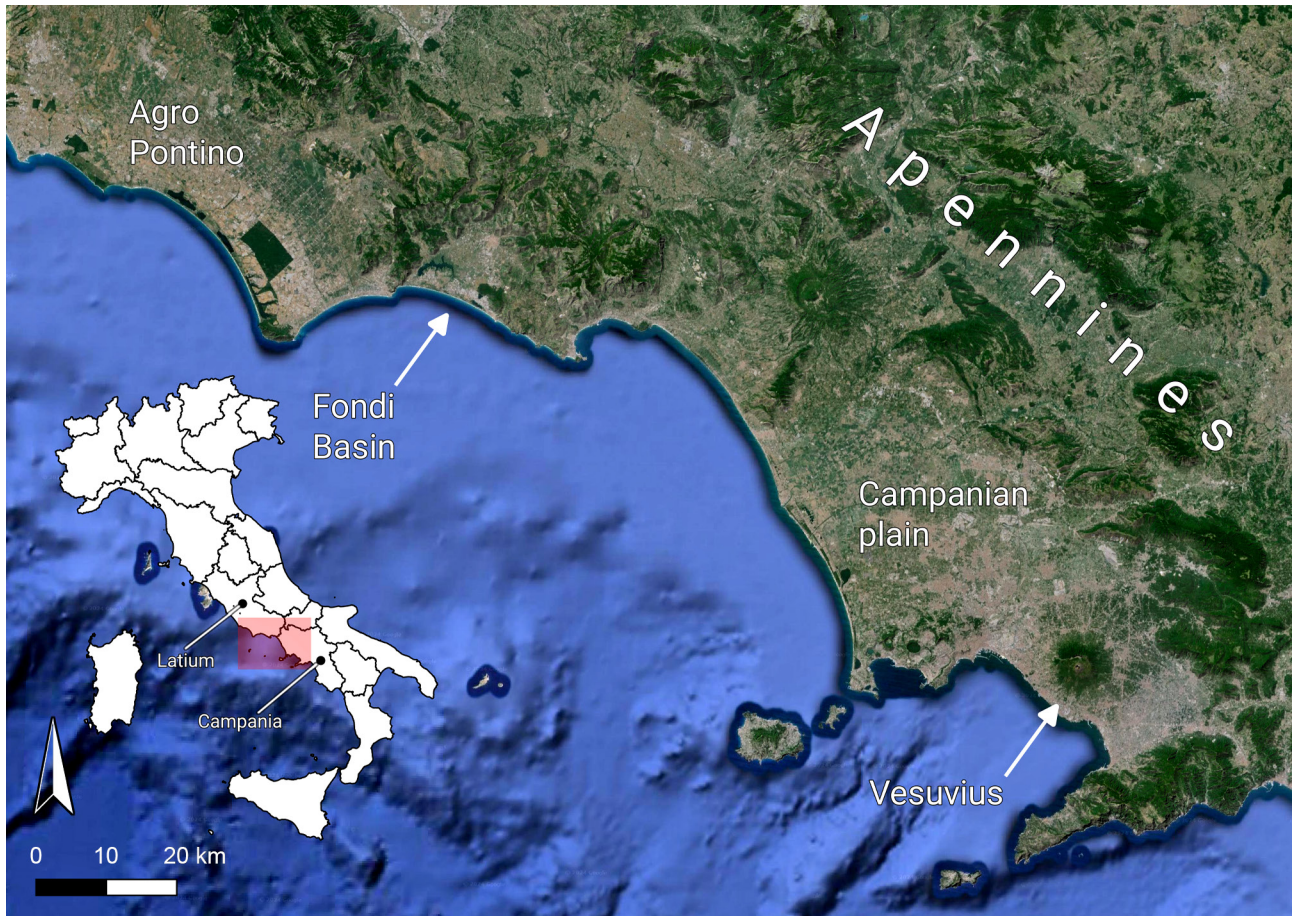


Fig. 1. Location of the Agro Pontino and the Fondi basin (map Luca Alessandria/GIA).

plains, located c. 60 km south of Rome and between 90 and 140 km north-west of Mount Vesuvius.<sup>2</sup>

The programme's principal hypothesis was that people living in the surroundings of Mount Vesuvius in the Early Bronze Age would have fled the proximal effects of the eruption – pyroclastic flows and heavy ash falls – to the relative safety of nearby areas where they might build a temporary or permanent new existence. The Fondi basin and the Agro Pontino coastal zone would have been the most easily accessible and suitable area to migrate to (Fig. 1), and if the number of migrants was sufficient, these migrants would then have left traces in the cultural record of the area, for example by introducing new pottery styles, as well as have an impact on the environment that would have been detectable in the palaeobotanical record.

<sup>2</sup> The team consisted of Dr. Luca Alessandri, Prof. Peter Attema and Dr. Martijn van Leusen (GIA); archaeobotanists Dr. Marieke Doorenbosch and Dr. Mike Field (Faculty of Archaeology, University of Leiden); and physical geographers Dr. Wouter van Gorp (GIA) and Prof. Emeritus Jan Sevink (Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam).

The discovery, in 2009, of a thin tephra layer of the Avellino Event in sediments in the former wetlands of the Pontine plain and the Fondi basin by team member Jan Sevink meant that the team was able to work with a precise chronological marker when reconstructing the Bronze Age environment (Fig. 2) (Sevink *et al.* 2011). In follow-up research, the date of the eruption was firmly established, at c. 1900 BCE (Alessandri 2019; Sevink *et al.* 2021). To find traces of the hypothetical migrants in the post-Avellino eruption landscape, a sophisticated, interdisciplinary methodology was employed, which we discuss below. First, we briefly introduce the previous research activities on which the Avellino Event project was able to build.

The Agro Pontino and the Fondi basin have been the subject of detailed physical-geographical investigations, starting with the compilation of a soil map of southern Lazio and adjacent Campania by researchers at the University of Amsterdam (Sevink *et al.* 1984). This map then formed the basis for the landscape archaeological work of the Agro Pontino Survey project, led by researchers at the University of Amsterdam (1979–1989) (Holstrom *et al.* 1989; Voorrips *et al.* 1991), and was also extensively used by the Pontine Region Project, led by researchers at the University of

Groningen (1983–present) (Attema 1993; Attema *et al.* 2010, 2019). Both of these long-term landscape archaeological projects conducted palynological and geoarchaeological investigations alongside archaeological surveys, providing insight not just into the region's settlement record from protohistory to Roman times, but also into the biases affecting that record (Van Leusen 2002; Van Joolen 2003; Van Leusen *et al.* 2011; Feiken 2014). Sedimentation during the later Holocene proved to be particularly influential: geoarchaeological investigations in the former wetlands of the Pontine Plain carried out within the context of the Pontine Region Project gave the first hard evidence of the existence of a hidden Bronze Age settled landscape, and this was then further studied through geoarchaeological work and palynological research in the course of the Avellino Event project. This resulted in a detailed palaeoenvironmental map showing the landscape around the time of the Avellino eruption (Van Gorp & Sevink 2019, 2023; Van Gorp *et al.* 2020). Together, these studies provided a firm archaeological, environmental and chronological basis for the Avellino Event research programme. Below, we give an outline of the phases of and results achieved by the programme and its various sub-projects.

## 2. Main phases and results of the Avellino Event project

In the first year of the Avellino Event project (June 2016), the research team organized an expert workshop to discuss the project's main hypotheses (Sevink *et al.* 2019: 130). This workshop, entitled *Distal Effects of Volcanic Eruptions on Pre-industrial Societies*, was hosted by the Osservatorio Vesuviano, the oldest volcanological observatory in the world, located near Herculaneum, Italy. At this venue, Avellino Event project team members convened with an international group of leading scholars in the study of the effects of volcanic eruptions on pre-industrial societies. Two questions, deriving from the team's main hypothesis of a substantial refugee in-migration into the Fondi basin and the Pontine plain, were central to the debate:

- What was the primary impact of Avellino tephra deposition in the distal areas, where far smaller but well-recognizable amounts of tephra were deposited? This question was broken down into sub-questions, such as how much tephra fell, whether this tephra was toxic, and what impact tephra deposition had on human health and local economy.
- Where did the population of Campania flee to and what (secondary) impact did this migration have on the surrounding, distal landscapes and communities? This question was broken down into whether any cultural impacts are visible in the archaeological record, whether an influx



Fig. 2. A coring carried out on the Fondi plain by Prof. Emeritus Jan Sevink. A: Entire core. B: Tephra portion of the core (photos Peter Attema/GIA).

of migrants shows up in the isotopic values of human bones and perhaps even aDNA of human remains, and whether changes in the nature and intensity of land use show up in the precisely dated palaeoecological records of sediments holding the tephra layer.

Below, we will systematically go into these questions and the various research activities carried out to answer them, referring to the papers and other deliverables that

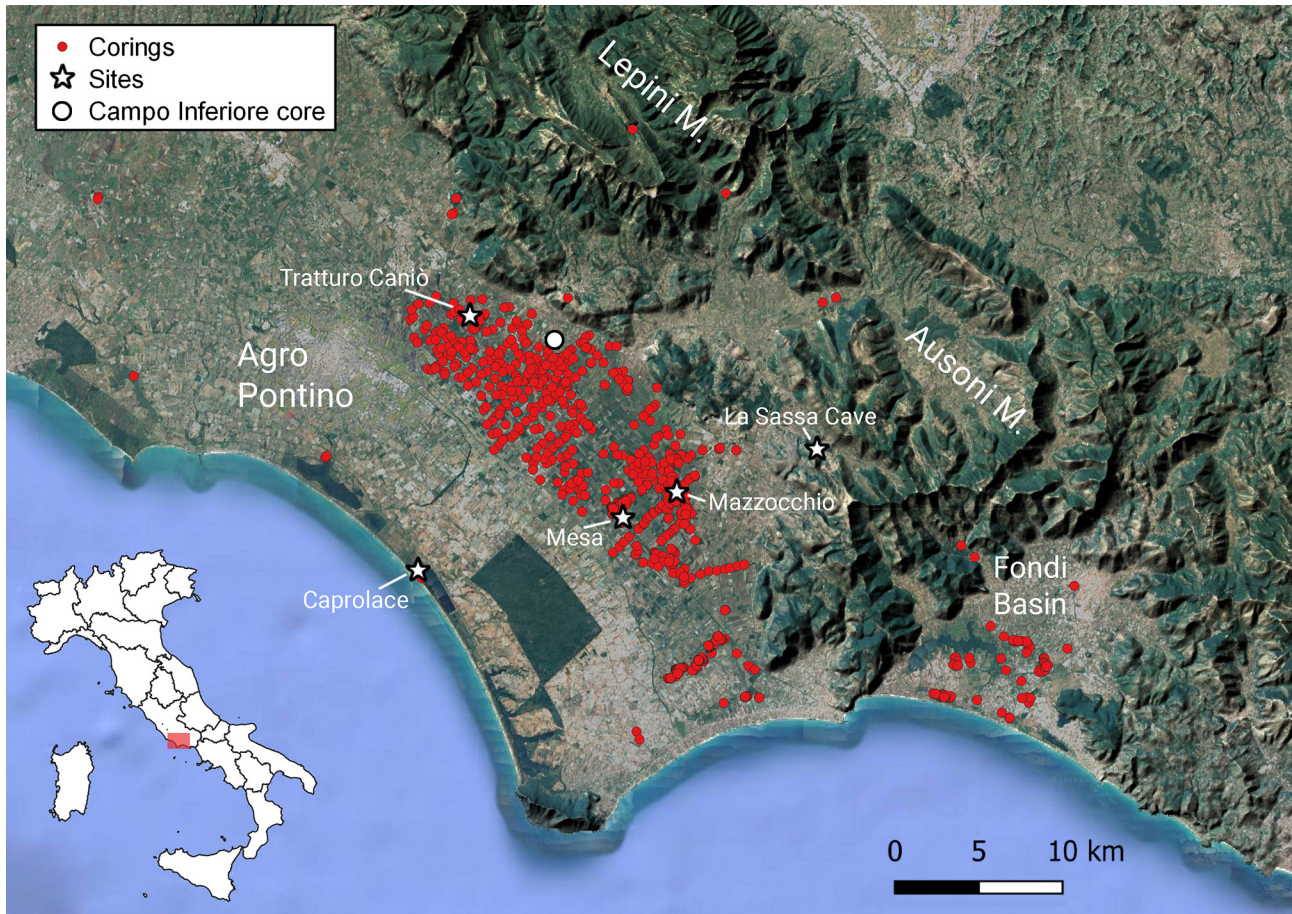


Fig. 3. Locations of soil pits and corings analysed as part of the project (map Luca Alessandri). M. = Mountains. Coordinates EPSG 32633.

resulted – including spin-off research and publications that were not part of the original design of the Avellino Event programme. It must be noted, however, that by the time of the expert workshop, the team had already reclassified the central idea of a substantial refugee in-migration as improbable, because the first palaeobotanical records created in the sub-project Distal Palaeoecological Impacts of the Avellino Event had already led post-doctoral researcher Marieke Doorenbosch to conclude that there was no evidence of an increased human impact on the landscape following the tephra deposition event around 1900 calBC. This early conclusion remains unchanged after further palaeobotanical research and was soon corroborated by the results of the sub-project Distal archaeological Impacts of the Avellino Event, carried out by post-doctoral researcher Luca Alessandri, who found no increase in settlement density immediately after the Avellino Event.

### 3. Impact of tephra deposition

Doorenbosch and her supervisor at Leiden University, Mike Field, studied and published macro-fossil and palynological assemblages from several soil pits holding tephra layers in the Fondi basin and the Pontine plain.

Their studies resulted in a detailed reconstruction of the late Early Bronze Age and early Middle Bronze Age environment (Doorenbosch & Field 2019; Doorenbosch 2023).<sup>3</sup> The 2019 publication concentrated on the palaeobotanical analysis of samples from the soil pit known as Femmina Morta 197, in the Fondi basin (Fig. 3), which holds two tephra layers: the upper one was identified as the Avellino tephra from Vesuvius, and the lower one as Astroni-6 eruption tephra dated to 4.23 ka BP (Arienzo *et al.* 2015) from the Campi Flegrei caldera (Sevink *et al.* 2020), just north-west of Naples.<sup>4</sup> Doorenbosch and Field (2019) observe that both ashfalls had left the succession of predominantly natural vegetation in the Fondi basin unaltered all through the period under study, and that there are no signs of human impact on

3 For an extensive description of the modern vegetation in the area, see Doorenbosch and Field (2019).

4 There is evidence for the presence of yet another, very thin tephra layer located a few tens of centimetres above the Avellino tephra, which has been identified as the Avellino Pumice (AP2) (sample 198-L; Sevink *et al.* 2020) dated to 1689 ± 24 cal BC (Jung 2017) or 1730-1630 cal BC (Passariello *et al.* 2010).

the natural vegetation. This led them to the conclusion that the Avellino ash fall had no adverse effect on the vegetation in the Fondi basin and that population levels were low in the Bronze Age, confirming the picture arising from the archaeological record so far, in which Bronze Age sites are extremely rare. Here we must be cautious, however, as the Fondi basin has seen little systematic archaeological research (Alessandri 2013).

The outcomes of this preliminary study were corroborated by the full programme of palaeobotanical studies of soil pits and of cores taken in the Fondi basin and the Pontine plain, and published by Doorenbosch (2023) (Fig. 3). Adding new data to the latest palaeoenvironmental review by Bakels *et al.* (2015), and combining our work with work done on the Iron Age, the Roman period and the early medieval period within the framework of the Pontine Region Project (Haagsma 1993; Van Joolen 2003; Feiken 2014), we now have at our disposal an extremely rich body of local and regional palaeobotanical evidence covering three millennia, from the 4200 BP ‘cool and wet’ climatic event to the period of increased anthropization of the Pontine plain and Fondi basin that occurred from the Middle Bronze Age onwards. For the impact of the 4.23 ka BP event, we refer to Doorenbosch (2023).

On the basis of her study, Doorenbosch (2023:229) concludes that the palaeobotanical data collected for the late Early Bronze Age vegetation record in the Pontine plain and the Fondi basin by the Avellino Event project reflects a relatively stable landscape hosting a mosaic of vegetation communities that were not significantly affected by human activities. 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 the regional or local vegetation.

#### 4. Quantity and possible toxicity of the ash fall and possible effects on human and animal health

Doorenbosch’s (2023) conclusion, however, does not automatically imply that humans and animals living in the Agro Pontino would not have undergone any short-term adverse effects from the ash falls of the Avellino Event or of the other eruptions for which we found evidence (Payne & Egan 2019, and references therein). Tephra is toxic and, depending on a range of factors, may have had a negative effect on the daily subsistence of humans and animals relying on the intake of crops, fodder, fruits, and water affected by volcanic ash. A review on the possible impacts of ash fall (among which toxicity) and societal responses to it, provided by Robin Torrence at the Avellino Event conference (Torrence 2019),

prompted Avellino Event project member Jan Sevink and colleagues from IBED to conduct a toxicity analysis of the Avellino tephra. They found that the sampled tephra and its adjacent sediment in several instances contained high levels of fluorine (Sevink *et al.* 2021). As specified by Sevink *et al.* (2021), fluorine from the ash fall would have become quickly immobilized as  $\text{CaF}_2$  (calcium fluoride) in the Ca-rich environment provided by spring waters from the Lepini mountains, whereas in Ca-poor environments, such as those prevalent in the anoxic clays and peat areas of the coastal wetlands, fluorine would have remained mobile. Any ash deposited on the vegetation in the peats of the Pontine wetlands may therefore have had a harmful effect and may have resulted in temporary health problems for people and animals. If such an effect occurred, it did not leave any signs in the archaeological record collected by the team. Given the paucity of archaeological evidence for the late Early Bronze Age, we also cannot evaluate a possible negative demographic effect. Therefore, we must conclude that the amount of Avellino tephra was perhaps, in theory, sufficient to provoke adverse effects on human and animal health, but that any such effects on demography, subsistence and economy cannot be measured given the current state of archaeological knowledge.

#### 5. Pontine plain and Fondi basin a refuge area?

Insofar as the sparse Early Bronze Age archaeological record from the Pontine plain and Fondi basin allows us to assess this, these areas appear to be part of the same cultural area as contemporary Campania. However, population numbers are seen to increase in the Pontine plain and Fondi basin only at the beginning of the Middle Bronze Age, about two centuries after the Avellino Event (Alessandri 2013). At the 2016 workshop, Italian proto-historian Alessandro Vanzetti suggested that areas to the east of Campania, which show strong pre-existing cultural affinities to Campania in their ceramic records, already entertained relationships of sorts and therefore may have been more receptive to the Campanian refugee population.<sup>5</sup> Ultimately, it should be possible to settle the question whether there was in-migration of a Campanian population into the Fondi basin and Pontine plain through isotopic study of human skeletal remains. However, because we were able to find only a few Early Bronze Age burials, and only when the end of the project was approaching, our planned research in this respect was frustrated.

<sup>5</sup> Archaeologists working on the archaeological record from the regions southeast of Campania may want to look into a scenario of demographic growth following the Avellino eruption.

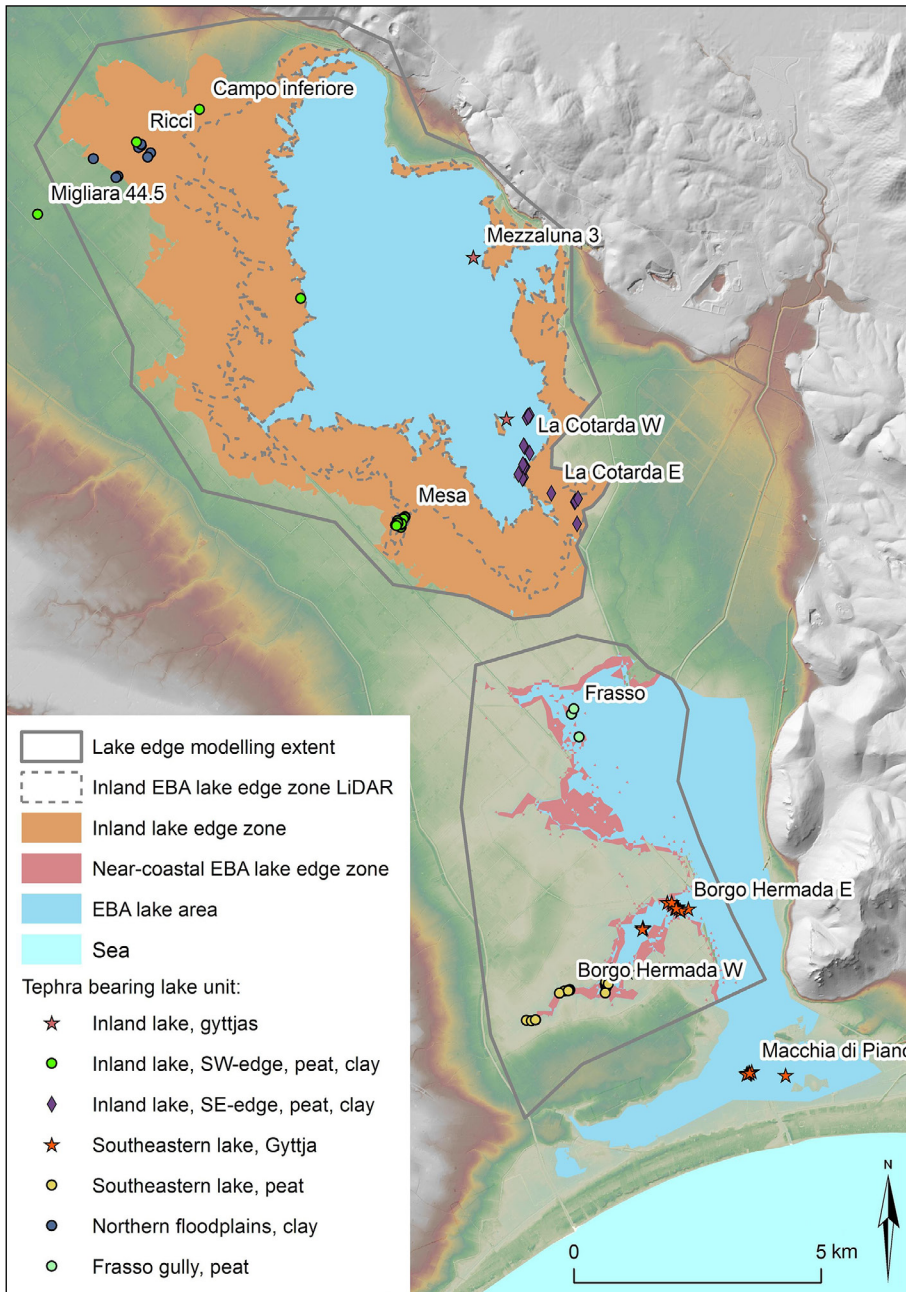


Fig. 4. Reconstruction of the Bronze Age palaeo-landscape of the Pontine plain around the time of the Avellino Event, with locations of soil pits and cores (map Wouter van Gorp/GIA).

The observed minimal impact of low population numbers on the Early Bronze Age landscape should, however, not be taken to mean that interventions in the landscape were absent. The team's corings and geophysical surveys in the surroundings of the Roman settlement of Mesa, along the Via Appia in the Pontine plain, have demonstrated the presence of ditches whose fill contains Avellino tephra, and which therefore must pre-date the Early Bronze Age (EBA) Avellino eruption (Tol *et al.* 2021). Farther to the north on the Pontine plain, from the site of Campo Inferiore di Sezze, we have evidence of substantial worked wooden beams dating to before the Avellino eruption, suggesting the nearby presence of a lakeside *palafitta* settlement (Bakels *et al.* 2015). Further modest interventions in the natural

landscape can be inferred from the archaeobotanical record for the period (Doorenbosch 2023), and from the recently excavated Mazzocchio site (Sevink *et al.* 2023). We must therefore conclude that during the EBA, the Pontine plain, and very likely also the Fondi basin, was only exploited by small communities.

## 6. Palaeoenvironmental reconstruction

The main result of the Avellino research programme is undoubtedly the large body of very detailed geological and palaeobotanical data, anchored by  $^{14}\text{C}$  and tephra chronological data, that has allowed the team to make a detailed and phased environmental reconstruction of the Pontine plain for the early phases of the Bronze



Age (Fig. 4). During that period, the Pontine plain had two lakes that formed a rich economic resource for the sparse communities living in the surrounding foothills of the Lepini and Ausoni mountains and on the marine terraces along the coast. It is not unlikely that the lakesides were settled, given that they were in the subsequent Middle Bronze Age and later periods. Towards the close of the research project, evidence was found for Bronze Age lakeside pile-dwellings at Mazzocchio/La Cotarda (see below, spin-off projects). In combination with earlier excavations by the GIA at Tratturo Caniò (Feiken *et al.* 2012; Cassieri *et al.* 2013), our knowledge of human settlement in the Bronze Age wetlands of the Pontine plain has been greatly increased, and the detailed environmental reconstructions now allow us to specify a targeted field strategy for the detection of further Bronze Age settlements. In addition, the team has made huge strides in the reconstruction of the *longue durée* of human–landscape interaction in the Pontine region, going well beyond the chronological focus of the Avellino Event project by providing insight in vegetation change and increasing human impact on the landscape in later periods as well. This is reflected in a recent publication on the origin, history and future of the Pontine Marshes (Sevink *et al.*, 2023).

## 7. Conclusions

Hypothesis testing is fundamental to science. The Avellino Event programme team refuted its main hypothesis, that the Pontine plain and Fondi basin functioned as a refuge area for people fleeing the great Bronze Age eruption of Somma–Vesuvius of c. 1900 BCE – on both archaeological and palaeobotanical grounds. We may therefore now conclude that it is more likely that refugees moved eastward and perhaps southward from the volcano. However, at the same time, the multidisciplinary approach adopted by the team has yielded significant insights into the scale and character of human communities on the Pontine plain and, to a lesser extent, on the Fondi plain before the Middle Bronze Age. The permanent habitation and exploitation of both areas must have been very modest in scale during the EBA, even though the team did find traces of land management in the form of ditches predating the Avellino Event, hence before c. 1900 BCE. The programme resulted in a detailed environmental reconstruction of the EBA landscape that can be used as a basis for further investigations of the human use of this landscape during the EBA. Moreover, it generated broader geological and palaeobotanical data that can be used for the reconstruction of the *longue durée* of human–landscape interactions on the Pontine plain and has therefore contributed greatly to the overall objectives of its long-running umbrella GIA research programme directed by Attema, the Pontine Region Project

(Attema *et al.* 2019). Lastly, it has generated a number of spin-off studies, some of which have developed into independent research projects.

## Spin-off projects

In one such ongoing spin-off project, carried out under the umbrella of the Avellino Event programme at the La Sassa cave in the Monti Ausoni, in collaboration with Prof. Mario F. Rolfo and F. De Angelis of Tor Vergata University (Rome, Italy), team member Luca Alessandri was able to excavate burials in a Copper Age to Middle Bronze Age cave, obtaining aDNA data from human remains that, together with data from other Italian *necropoleis*, constitutes the first genomic characterization of Bronze Age individuals from central Italy between 1950 and 1500 BCE (Saupe *et al.* 2021). An extensive set of isotopic analyses (C, N, Sr) was also performed on these remains in order to assess aspects of diet and mobility at the transition between the Copper Age and the Bronze Age. Finally, the large number of potsherds collected from the La Sassa cave allowed the team to obtain more information on the ceramic record and cultural influences of the periods prior to the late Middle Bronze Age (Alessandri *et al.* 2021).

The team's investigations of the lagoonal coastal strip did not, as mentioned above, result in the detection of any additional Early Bronze Age settlement; they did, however, result in the detection and partial excavation of an important Middle Bronze Age site on two islands in the lagoon of Caprolace. These excavations yielded what may be the earliest evidence to date for salt production in Italy using the *briquetage* method (Alessandri *et al.* 2019), a discovery that has spurred a successful application for a new Dutch Research Council-funded programme to investigate protohistoric to Roman salt production on the Lazio coast (Alessandri & Attema 2022).

During the geological fieldwork, Sevink and Van Gorp found indications for the existence of a Bronze Age pile-dwelling site at Casale Mazzocchio. This archaeological site was subsequently investigated by a team of six archaeologists, including Alessandri, who were commissioned by the authorities to carry out mitigative archaeological investigations prior to the planned construction of a solar plant, between April and July 2021. The site yielded a Middle and a Final Bronze Age phase. The metal finds from the site have already been studied by G. Melandri (in press), while an overview of its geological setting and landscape history was published by Sevink *et al.* (2023). The GIA was given the official permit to study and publish the excavated settlement remains and ceramic finds.

Over the past decades, the dating and chronostratigraphy of the marine terraces, which dominate the geology of the Agro Pontino, has remained an important topic. In the Avellino project, emphasis was on the Late

Pleistocene and Holocene history and deposits. However, quite some information was also gathered on the older Pleistocene terraces notably those from MIS5, represented by the Borgo Ermada (MIS5.3) and Minturno (MIS5.5) complexes. Further joint research in cooperation with Italian geologists and involving novel  $^{40}\text{Ar}/^{39}\text{Ar}$  analyses enabled the publication of a concise and well dated overview of the Quaternary history and chronostratigraphy of the Agro Pontino (Marra *et al.* 2023).

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## Appendix: Research and valorisation output

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- ALESSANDRI, L. & M.F. ROLFO. La Sassa cave (Sonnino, Italy), 7th Conference of Italian Archaeology, Galway, Ireland, April 2016.
- DOORENBOSCH, M., M.H. FIELD, L. ALESSANDRI, P.A.J. ATTEMA, C.C. BAKELS, W. VAN GORP, P.M. VAN LEUSEN & J. SEVINK, 2015. The Avellino Event: Distal palaeoecological impacts of the great Bronze Age eruption of Mount Vesuvius, Mediterranean Palynology Symposium, Rome, September 2015.

### Master theses

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- MERENDA, J., 2019. L'analisi archeozoologica dei livelli olocenici di Grotta la Sassa: campagne di scavo 2015-2018. Università di Roma Tor Vergata.

### Bachelor theses

- MARTINO, R., 2017. *Ursus arctos* (Ursidae, Mammalia) from the latest Pleistocene of Grotta la Sassa (Latina, central Italy), Università di Roma Tor Vergata.
- FIORILLO, A., 2017. Il rapporto uomo-orso nelle grotte italiane del tardo Pleistocene, Università di Roma Tor Vergata.
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### Dissemination

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