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Distal Effects of Volcanic Eruptions on Pre-Industrial Societies

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Editorial

Distal Effects of Volcanic Eruptions on Pre-industrial societies

1. Introduction

Major explosive eruptions are among the most unpredictable and serious natural hazards affecting human populations living near volcanoes, in particular during the pre-industrial era, when the nature of volcanism was not well understood. There has always been a fascination with the devastating impacts of volcanic eruptions, which were often attributed to actions of gods or demigods. Volcanoes were seen as the home of gods, whether in the classical world of Greece and the early Roman Empire, or in the Hawaiian and Māori mythologies in the Pacific 'Ring of Fire'. In the Age of Enlightenment, such interest led to the early development of volcanology as a branch of geology, with the first scientific observatory - the Vesuvius Observatory - being founded in 1841 by Ferdinand II, king of the Two Sicilies.

Volcanological, geochemical and mineralogical studies of eruptions, combined with developments in seismology and geophysics, led to an increased understanding of the nature of volcanism and the 'Deep Earth', i.e. the interior structure of the planet. They not only elucidated the role of such phenomena as mantle convection, mantle plumes, plate tectonics, continental drift, and magma differentiation, but also produced detailed insight into the eruptive history of many volcanoes and data on the composition of their ejecta. Using distal tephra layers, identified by their mineralogy and geochemistry, tephrochronologies were built that rapidly became of crucial importance in studies of deep-sea and ice-cap cores (see e.g. [Palais et al., 1987](#)), and of similar geoarchives such as lake records. Today, tephra layers that are identified by their chemical, isotopic or mineral composition are widely used for long-distance correlations of geoarchives (see e.g. [Zanchetta et al., 2011](#)), and advanced techniques such as $^{40}\text{Ar}/^{39}\text{Ar}$ Single Grain Dating ([Bogaard et al., 1987](#)) are increasingly applied for their dating (see e.g. [Giaccio et al., 2017a,b](#)).

To archaeologists, the most significant aspects of early volcanic eruptions were a) the exceptional preservation of remains of early civilizations underneath thick proximal tephra deposits, such as the Early Imperial settlement at Pompeii and the Minoan remains on Thera/Santorini, and b) the use of widespread, distal tephra layers as marker beds, allowing dating and long-distance correlation of different archaeological horizons.

In Old World archaeology, ages and correlations for a long time were founded on artefact typologies and history-based chronologies. For the early periods, the latter were deduced from early historical records from Egypt and Mesopotamia. Parallels exist in eastern and southern Asia (e.g. China and the Indus Valley). With the emergence of absolute dating methods, these chronologies were extended back in time and became more precise, but their reliability still depends very much on the availability of datable materials, and on the limitations of the absolute dating methods employed. This is demonstrated by the on-

going discussion on the High and Low chronologies for the Near East (see [Van Der Plicht and Bruins, 2001](#), and [Levy et al., 2005](#)).

A major advantage of a tephra layer, that acts as a marker horizon, is that it provides an extremely precise relative and, if well dated, absolute age for the contemporary landscape and its human occupation. In addition, geographical and temporal patterns in archaeological features at the time of the eruption may be identified if a tephra layer is present. A further advantage is that such marker beds enable the extension of chronologies beyond the range of radiocarbon dating. Examples include the Campanian Ignimbrite (CI) super-eruption (VEI 7) in Italy that dates from around 40 ka BP, at the margin of reliable radiocarbon dating, and the Toba eruption on Sumatra, Indonesia from around 75 ka BP. The CI-eruption is the largest known Late Quaternary volcanic event in the Mediterranean region and the tephra covers over 3.5 million km² of central and eastern Europe, and adjacent parts of Asia (see e.g. [Smith et al., 2016](#); [Giaccio et al., 2017a,b](#)). Tephra of the Toba eruption, which was of exceptional magnitude (VEI 8), allows even longer distance correlations, such as between Southeast Asia, India and Africa (see e.g. [Ninkovich et al. 1978](#); [Williams, 2012](#)).

Relevant for archaeological studies is the distinction between proximal and distal areas. In proximal areas, generally of relatively small extent, emphasis is largely on the preservation of remains from impacted communities. The impact of the tephra deposition is generally of such magnitude that resettlement is inhibited for significant periods of time. This implies that continuity in the occupation history may be broken and post-eruption remains are likely to testify to an abrupt break in material culture. In distal areas, with relatively minor deposition of tephra, preservation of remains by the tephra is less important and continuity in the occupation history is much more likely. However, even quite serious impacts can still occur in distal areas, such as those caused by toxic substances contained in the tephra (see e.g. [Grattan et al., 1999](#) on the impact on NW Europe of the Icelandic Hekla eruption).

The Avellino (AV) eruption of Mount Vesuvius dates from the early 2nd millennium BC and is a typical example of a major prehistoric eruption that had a severe impact on the contemporary inhabitants living in the area proximal to the cone. Following an initial low-magnitude eruption phase, two Plinian eruption phases occurred, followed by large phreato-magmatic explosions, the last of these dispersed tephra to the NNW. Earlier tephras were dispersed to the NE ([Sulpizio et al., 2010](#)). The eruption devastated the landscape and the flourishing Early Bronze Age communities then occupying the southern part of the region of Campania. It was only during construction work in 1972, near the town of Palma Campania, that the first settlement buried by the AV eruption was discovered ([Livadie and Amore, 1980](#)). Since then, archaeologists have uncovered and described many more Early Bronze Age settlements of this so-called 'Palma Campania facies', all

stratigraphically correlated to the eruption (Talamo, 1996; Livadie, 1999; Di Vito et al., 2009; Saccoccio et al., 2013). Some of the remains, perfectly preserved by the eruption products, have been described as ‘the Bronze Age Pompeii’.

The AV eruption wrought both immediate and long-lasting havoc in much of the Campanian coastal plain. Dramatic evidence is available to show that people were forced to flee taking only their most valuable possessions and were unable to save all of their livestock (Passariello et al., 2009). However, they seemingly were able to escape alive, given the scarcity of victims encountered underneath the ash, in sharp contrast to the excavations at Pompeii and Herculaneum, where victim remains abound. A recent review of archaeological research in Campania (Di Lorenzo et al., 2013) concludes that, whilst a few areas seem to have recovered within decades after the AV eruption, it took up to several centuries before the Bronze Age population had recovered to pre-eruption levels.

Farther away from Mount Vesuvius, the impact of this eruption was less devastating, the thickness of the distal tephra layer being in the order of a few centimetres only. In these distal areas, the AV ash was found in sediment cores from lakes and from the Adriatic and Ionic seas, where they constitute an excellent marker bed (e.g. Sulpizio et al., 2008; Zanchetta et al., 2011). Though widely encountered – from Lago Accesa in Tuscany (Magny et al., 2007), to Lake Shkodra in Albania (Sulpizio et al., 2010) and the Sea of Marmara in Turkey (Çağatay et al., 2015) – studies were largely limited to geoarchives in sediment cores. No attempts were made to use this marker for reconstructions of contemporary distal landscapes and study of prehistoric cultures that occupied them. The discovery of an almost continuous AV tephra marker horizon in the Holocene sedimentary fill of the Agro Pontino graben in Southern Lazio, about 100 km NW of the eruption centre changed this situation (Sevink et al., 2011). Its relevance for the Early Bronze Age archaeology of that area was further elucidated by Sevink et al. (2013) and Feiken (2014), and was most evident in the excavation at Tratturo Caniò (Feiken et al., 2012) and at Ricci (Bakels et al., 2015). The area concerned contained geoarchives that were highly suited for palaeogeographical and ecological reconstructions providing an insight into the contemporary landscape, nature of habitation and prevailing environmental conditions.

In summary, the proximal impact of the AV eruption was severe, but the population largely escaped to ‘safe areas’ of which the location is still unknown, but might well include the coastal areas of Southern Lazio, where tephra deposition had little impact on the environment. These coastal areas are suited for studies on the distal impacts of this eruption. Given this background, two major questions come up with regard to the distal impacts of the AV eruption: 1) what was the primary impact of tephra deposition in the distal areas, where far smaller but well recognizable amounts of tephra were deposited? and 2) where did the population of Campania flee to and what (secondary) impacts did this migration have on the surrounding, distal landscapes and communities?

The first question breaks down into more detailed questions such as ‘how much tephra fell?’, ‘whether this tephra was toxic?’, ‘what impact tephra deposition had on geomorphological and hydrological processes?’, and ‘what impact it had on human health and local economy?’. The second question breaks down into questions such as ‘whether any cultural impacts are visible in the archaeological record?’, ‘whether an influx of migrants shows up in the isotopic composition and eventually DNA of human remains?’, and ‘whether changes in the nature and intensity of land use show up in the extremely precise palaeoecological records of sediments holding the tephra layer?’

Since the coastal basins of Southern Lazio offer very good opportunities for research that aims to answer such questions, the Universities of Groningen and Leiden developed a joint research project that focused on the two central topics and on the Agro Pontino and Fondi basins in southern Lazio. This multidisciplinary four year project, entitled ‘The Avellino Event: cultural and demographic effects of the

great Bronze Age eruption of Mount Vesuvius’, was funded by the Dutch National Research Organisation (NWO) and began in June 2015.

This special issue, based on an international expert meeting held in June 2016 at the Vesuvian Observatory, is composed of papers addressing the two major questions mentioned above, which are not only relevant for the AV eruption, but also for understanding the potential direct and indirect distal impacts of such eruptions in general.

2. This special issue and summary of the papers

The papers presented in this special issue provide an up-to-date overview of relevant aspects of and current knowledge on distal effects of major volcanic eruptions in pre-industrial societies. Though emphasis is on the Early Bronze Age AV eruption, the set of ideas and methods presented is exemplary for such studies on early impacts of volcanic eruptions, and illustrates the value of a multidisciplinary approach. Contributions are grouped into four sections presented below.

2.1. Setting the general framework: status quo of research into the geological, ecological, health and cultural impacts of volcanic eruptions

Payne and Egan set out in general terms how large volcanic eruptions may have major impacts on ecosystems, building on studies of historical eruptions from all over the world. In her review paper, Torrence emphasizes that disasters are fundamentally social in nature and that impacts of eruptions on prehistoric societies very much depend on their social responses. Zanchetta and co-authors provide an up-to-date review of studies on central Mediterranean palaeoclimate archives and tephra layers that are relevant for the Bronze Age of this region.

Payne and Egan stress that the impacts of volcanic eruptions are stochastic and that, because the largest, most damaging volcanic events have not occurred in the recent past, considerable interest exists in past eruptions as an analogue for possible future events. An important aspect is how palaeoecological study can throw light on direct distal volcanic impacts (mainly ash falls). Processes, by which volcanic eruptions affect ecosystems are reviewed, followed by a discussion on how palaeoecological research can enhance our knowledge of palaeovolcanic impacts and some of the challenges which such studies face.

The focus is particularly on tephro-palaeoecological studies, which address changes in the abundance of microfossils (e.g. pollen, diatoms, and testate amoebae) across tephra layers preserved in sediments. In the discussion, the importance of impacts from volcanic tephra, volatiles and volcanically induced climate change are stressed, since these are likely to be the most spatially extensive impact mechanisms. Special attention is given to the importance of considering the taphonomy of tephra and microfossils when attempting to identify volcanic impacts. Another topic is the extent to which it is possible to distinguish volcanic impacts from non-volcanic processes and random variability. Since the focus of this special issue is the Mediterranean the authors conclude by discussing the particular issues which may apply in this region, including the availability of suitable archives and preservation conditions.

Torrence reviews key concepts that are useful for structuring research on social responses to volcanic eruptions among pre-industrial societies. Concepts that are extensively discussed include societal vulnerability, resilience, and adaptation, based on studies of volcanic disasters impacting on primitive societies from all over the world. Beginning with vulnerability, the importance for archaeological research of a temporal viewpoint that effectively incorporates studies of resilience, change, and adaptation is appraised, and the attention is drawn to temporal and spatial scales in human responses to disasters. A discussion of the potential effects of volcanic disasters on food procurement is presented to illustrate the value of broadening the scale of research beyond a focus on initial impacts. Lastly, Torrence presents a framework for contextualising research on the AV volcanic event, stressing the complex nature of human responses to disasters and

importance of the resilience of social groups.

Zanchetta, Bini, di Vito, Sulpizio, and Sadori provide a geological framework for the study of prehistoric Holocene volcanic impacts in the central Mediterranean area by reviewing the frequencies, chronology and magnitudes of the major eruptions. The significance of this framework for human impact studies is treated in detail, with a focus on its completeness and reliability. Three widely dispersed tephra layers are distinguished: Agnano Mt Spina from the Campi Flegrei (ca. 4.4 cal ka BP), Avellino from the Somma-Vesuvius (ca. 3.9 cal ka BP), and the so-called FL from the Etna (ca. 3.3 cal ka BP). Some records have severe chronological biases, posing important limitations for the use of these archives in defining palaeoclimate conditions during the period concerned. Agnano Mt Spina tephra seems to occur at the beginning of a centennial scale period of climatic deterioration, whereas AV tephra occurs during a wetter period and probably marks the end of this event. The dry event bracketed by the two tephra seems to be correlated with the so-called “4.2 event”. FL tephra from the Etna seems to herald a new climatic deterioration at ca. 3.3–3.2 cal ka BP. Although the general framework is still incomplete, these three tephra layers play a fundamental role in synchronizing archives, and can lead to the definition of a detailed palaeoclimate framework of the Bronze Age in the central Mediterranean region.

2.2. Distal impacts: comparative cases

The Minoan Santorini eruption is one of the best-known examples of a prehistoric volcanic eruption in the Mediterranean region and serves as a comparative case. The paper by *Driessen* brings us up to date with the latest thinking about its distal impacts, both direct and indirect, including precursor events, and evidence for recovery/reoccupation. The paper by *Bruins and co-authors* deals with very special situations in which distal tephra may be encountered (caves) and their identification, with emphasis on the Minoan eruption. Though considerably older, the Laachersee eruption, which has been thoroughly studied for its impact on the contemporary Late Palaeolithic cultures of Central and Northern Europe, represents an interesting comparative case. *Riede* describes the deep impact of this eruption on the contemporary early cultures in the huge area affected by this eruption.

The review paper by *Driessen* readdresses the archaeological evidence that can be used to assess the distal impacts of the second millennium BC Santorini eruption on the Minoan civilization that flourished on the island of Crete. By paying attention to a greater chronological resolution of the situation prior to, during and after the eruption, the impact of the event can be better understood. Arguments are brought forward to show how the societal system on Crete was already under pressure and weakened before the eruption. It is also shown how especially the eastern part of the island suffered from volcanic ash fall which further disrupted society, leading to a continuing and prolonged process of disintegration, characterised by multiple site destructions and various modifications in architecture, pottery production and ritual. The distal effects of the eruption hence exacerbated the situation leading to a state of social unrest and a process of breakdown during the post-eruptive period, which only came to end when a new Mycenaean-inspired regime installed itself at Knossos.

Bruins, Keller, Klügel, Kisch, Katra, and van der Plicht demonstrate how the comparatively sheltered position of some cave environments, protected from rain and runoff, may provide prime sedimentary evidence of distal tephra that has been eroded in the open landscape. The Late Pleistocene Campanian Ignimbrite super-eruption, for example, has been recorded in caves in the form of visible tephra layers and as crypto-tephra. The Minoan Santorini eruption may have been the largest known Holocene eruption in the central Mediterranean region and as such produced a major tephrochronological marker bed, but its tephra had not yet been found in caves. Novel observations on a distinct tephra layer from the latter eruption in the Pelekita cave in eastern Crete are presented. The layer seems to represent an air fall deposit,

showing distal phases of the Minoan Santorini eruption that may perhaps be correlated with the proximal tephra eruption phases at Thera. The thickness of the volcanic ash fall on Crete is re-evaluated in light of the new data, as well as its possible impact on Minoan society.

Felix Riede describes the Laacher See eruption (12,920 BP) as offering a strong case study for gauging the extent of distal environmental and cultural impacts of past eruptions. During this event, eruption products briefly dammed the River Rhine and then released a flood wave, whose effects can be followed hundreds of kilometres downstream. At this time hunter/gatherer populations in northern Europe became isolated as ash fallout spread across Europe from the Alps to the northern end of the Baltic Sea. This contribution shows that the risks and impacts of an eruption do not necessarily diminish but rather change with distance from the eruption source, and that it is possible to demonstrate cultural impacts even very early on.

2.3. Bronze Age societies and the Avellino eruption: status quo in current research

Research has shown that the proximal tephra from the AV eruption covers a well-preserved Early Bronze Age agricultural landscape. This prompted extensive research on the Bronze Age tephrochronology and impacts of successive Vesuvian eruptions of which the AV eruption is a major one, as well as on the archaeological remains and landscapes. Various aspects of this research are dealt with, concentrating on proximal tephra and areas. The papers presented evidence the differences in opinion that still exist on the recolonisation of the proximal area after the AV eruption. *Di Vito and co-authors* review the current knowledge of the AV eruption and its proximal and distal impacts, with emphasis on direct and indirect physical impacts of such major Plinian eruption. *Vanzetti and co-authors* focus on the buried Campanian field systems, covering a larger period of time (Copper to Early Bronze Age) and paying particular attention to the reconstruction of the ancient landscapes and resilience of their agricultural use. *Livadie and co-authors* summarise and review the status quo of the archaeological understanding of life ways and cultural traditions in the Campanian plain, and then go on to discuss the processes of abandonment and recolonisation. *Alessandri and co-authors* evaluate the existing typology-based chronologies for the Italian Bronze Age on the basis of a thorough reinterpretation of currently available ¹⁴C datings and confront these with the existing tephrochronology.

Di Vito, de Vita, Sulpizio, Talamo, and Zanchetta review the local impacts of the AV eruption and their duration, based on the available archaeological data, the study of geological and archaeological sequences exposed in excavations, and the reconstruction of the volcanic phenomena affecting single sites. The land was rapidly abandoned before and during the eruption, with rare post-eruption attempts at resettlement of the same sites inhabited previously. The distribution and stratigraphy of alluvial deposits in many of the studied sequences indicate that the scarce presence of humans during the post-AV phases 1 and 2 of the Middle Bronze Age can be attributed to adverse site conditions brought about by slope instability, resulting from the deposition of loose fine pyroclastic material and climatic conditions, which favoured run-off and led to long-lasting alluvial processes. A significant resettlement of the territory occurred only hundreds of years after the Pomice di Avellino eruption, during phase 3 of the Middle Bronze Age. The study demonstrates the role of volcanic and related phenomena from a Plinian event in the settlement dynamics of a complex territory like Campania.

Vanzetti, Marzocchella, and Saccoccio summarise the current knowledge on the field systems in the Piana Campana, including brand new data from the Gricignano area. Settlements, burials, landscape, and agrarian infrastructures (fields, tracks, wells) show an intense and continuous human presence since at least Late Neolithic times (ca. 6.2 ka cal BP). This conclusion is supported by palynological data. The resulting pattern shows the continuity of the Copper and Early Bronze

Age field systems during the time span between ca. 4550 and 3850 cal BP (Agnano Monte Spina and Avellino eruptions). The intermediate Phlegraean eruptions, probably originating from Astroni, did not have a great disruptive effect, probably only forcing a re-arrangement of the field system and possibly some settlements. Lastly, the observed impacts proximal to the volcano as well as the expected impacts further away are discussed, and any evidence for the recovery and reoccupation of abandoned areas.

Livadie, Pearce, Pizzano, and Delle Donne start by summarising and reviewing the status quo of archaeological understanding of life ways and cultural traditions in the Campanian plain. They then go on to discuss both the evidence and expectations for impacts proximal to the volcano as well as further away, including recent unpublished results. The archaeological data indicate that the local population recovered quickly, soon recolonizing the proximal volcanic area. These results are important, as they show that the real crisis in human activity is not simply due to the effects of the AV eruption, but rather results from an intense and long-lasting period of environmental change, brought about by the accumulated effects of several eruptions. These results also allow for reconstruction of the settlement pattern that characterised the Middle Bronze Age in the Somma/Vesuvius area. Lastly, they support a re-dating of the climax of the crisis to a few generations after the traditional transition between the end of the Early Bronze Age and the beginning of the Middle Bronze Age 1/2.

The paper by *Alessandri* focuses on the problem that societal impacts and their precise timing are not just caught up with the phasing and dating of volcanic eruptions (for these, see the contribution by Di Vito et al.), but more fundamentally with the precision and reliability with which we can determine cultural impacts and responses. This paper describes the archaeological typology and chronology surrounding the AV eruption and how these have been constructed. Central in this paper is a Bayesian model for the chronology of the AV eruption and its consequences for the Italian chronological framework at the beginning of the Bronze Age. The limitations this imposes on the study of the distal AV eruption impacts in southern Lazio are described and ways in which further study can overcome these limitations.

2.4. AV impacts in Southern Lazio: status quo in current research

Within the current Avellino Event project *Van Gorp and Sevink* pay particular attention to the reconstruction of the Early Bronze Age landscape and vegetation in the coastal areas of Southern Lazio. This landscape reconstruction serves to identify areas that might conserve archaeological archives in the right context (with associated AV tephra), to identify sites suited for palaeoecological studies, and to develop settlement and exploitation models for the immediate pre- and post-eruption landscape. In the palaeoecological study by *Doorenbosch and Field* emphasis is on the vegetation and potential changes in land use that might reflect temporal patterns in human occupation, which could eventually be linked to migrations resulting from the massive impact of the AV eruption further south in Campania.

Van Gorp and Sevink present a first detailed reconstruction of the coastal landscape at the time of the AV eruption, within a broader reconstruction of the late Würmian and Holocene evolution of this region. In the Agro Pontino, three subareas could be distinguished, which differ with respect to the impacts of sea level lowering during the Würmian and Holocene sea level rise. They exhibit systematic differences in sedimentary built-up and occurrence of intercalated AV tephra, as well as in potential for conservation of suited sedimentary archives, i.e. conserving relevant archaeological and palaeoecological remains. In the Fondi basin a less complex situation was encountered, with a fluvial dissected landscape that was filled in later during the Holocene, but its teprochronology is more complex. Results will serve to build a framework within which more detailed studies of the AV impact can take place.

Doorenbosch and Field describe how the direct and indirect distal

impacts of the AV eruption are being studied (2015–2016) in Southern Lazio, employing micro and macro botanical methods to arrive at palaeoenvironmental reconstructions at a sufficiently high chronological resolution. They set out modelled (hypothetical) impacts against those actually observed and discuss the strengths and weaknesses of this approach.

Results from a first core in the Fondi basin with two tephra layers, of which the upper is the AV tephra layer, allowed the reconstruction of a late Early or early Middle Bronze Age landscape and its vegetation. The palynological data show a natural landscape that was unaltered by anthropogenic activity and in which a mosaic of vegetation communities existed. Charcoal deposition was probably the result of natural fires within in the catchment. The data suggest the deposition of the tephra did not affect the vegetation in the area and no evidence was found for an increased human impact on the vegetation following the AV eruption.

3. Remarks for future research

A final session during the June 2016 workshop was devoted to the implications for the Avellino project of the various ideas and results presented. This breaks down to the various topics studied within the project and hypotheses on which these are based. Below an overview is given of the major topics and recommendations.

3.1. The general hypothesis: migration of the Early Bronze Age campanian population to Southern Lazio

The June 2016 workshop discussed one of the project's main assumptions – that migration of Campanian population to the coastal areas of southern Lazio was very likely to have occurred – and noted that a more probable scenario, given existing social ties as seen in the material culture, would be for such migration to be directed to the east (across the Apennines) and south. A complicating factor for the detection of such migrations may then be the ethnographically known phenomenon that migrants are tolerated but directed to marginal areas – for which we tend to have the worst archaeological records. Anyhow this is worth pursuing, and a big part of it must be to put more research into the reconstruction of the demography of Bronze Age populations, similar to Andreas Zimmermann's work for the German Neolithic in the Rhine valley (*Zimmermann et al., 2009*). Moreover, it was felt that studies in these eastern and southern areas that aim to identify such migrations would be truly worth pursuing.

3.2. Use of palaeoecological data as indicator for (changes in) population densities

The coring and palynological work so far done by the AEP, and presented in the paper by *Doorenbosch and Field*, puts (mainly qualitative) upper limits on the immediate pre- and post-AV settlement density, and strongly suggests that no substantial 'Campanian' immigration took place. However, prospection methods should be further developed so that we can obtain the more reliable and detailed estimates of settlement densities per period and landscape zone that form the basis for demographic reconstructions. Moreover, it is stressed that changes in vegetation may have other influences than land use, including climate change and chemical impact of tephra deposition (see 3.3).

3.3. Chemical impacts of tephra deposition

It emerged from the June 2016 workshop that the Avellino Event project had been ignoring the potentially significant chemical impacts of distal ashes – mainly in terms of toxicity cascading down the ecological network to ultimately affect the human population. Such impacts are often less dramatic but affect much larger areas than the more

proximal impacts do. Some inroads are currently being made (e.g. an on going UvA toxicity study), but there is clearly scope for a much more extensive study into these effects, combining geochemistry and palaeoecology. It should be emphasized that this aspect seems to have been overlooked in all studies dealing with the impacts of the AV eruption and other early eruptions in the Mediterranean. Remarkably, studies on recent impacts of Vesuvian eruptions show that such toxic substances indeed have serious impacts on human health, and in Campania fluorosis is rather widespread (see e.g. Cubellis et al., 2016) and has been observed in studies on skeletal remains from victims of the Pompeian eruption (Petrone et al., 2013).

3.4. Tephra layers and their identification

The appearance of multiple tephra layers in test pits and corings in Southern Lazio has complicated the goal of being able to securely identify the AV-tephra, but it also offers the possibility of establishing further chronostratigraphical anchors for central Italy. The situation is probably indicative for Italian distal areas in general and underlines the importance of detailed studies of Holocene sedimentary archives aiming at identification of intercalated tephra. This is particularly important because material that can provide reliable ^{14}C dates is hard to find.

Subsidiary pictures

Front: The Osservatorio Vesuviano, the oldest volcanological observatory in the world, hosted the international expert meeting on Distal Effects of Volcanic Eruptions on Pre-Industrial Societies.

Back: The Osservatorio Vesuviano during the 1906 eruption, one of the two paroxysms of the last century. After its foundation (1841) the Observatory, now section of the Istituto Nazionale di Geofisica e Vulcanologia, allows the study and surveillance of the most famous volcano of the world (Photo from the Osservatorio Vesuviano historical collection).

Acknowledgements

This special issue of *Quaternary International* is based on contributions of a multidisciplinary group of scientists during the international expert meeting, which was held in Naples from 5–7 June 2016 within the framework of the Avellino Event research project and was funded from a Netherlands Organization for Scientific Research ‘Free Competition’ research grant nr. 360-61-060 (main applicant Peter A.J. Attema).

The workshop was organised by Martijn van Leusen at the Rijksuniversiteit Groningen (Netherlands) together with Mauro di Vito at the Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano at Naples (Italy), with extensive support by Sonia Filatova in logistic matters and the preparation of the precirculated abstract book, and by Bernd Danhof together with INGV staff for the transport between the hotel at Torre Greco, the workshop venue, and Naples’ airport/railway station.

Participants convened at the Osservatorio Vesuviano, on the slope of the Vesuvius, a famous scientific centre that was made available by the Italian Institute for this occasion (see front page). We sincerely acknowledge the director of this institute and its staff for this contribution, more specifically Mauro Di Vito, Sandro de Vita, Ilenia Arienzo, Antonio Carandente and Marcello Martini. They also provided the participants with a well-guided tour to the Vesuvius crater and various sites in the surroundings to better understand the nature of this sometimes-devastating volcano (see back page).

A number of participants directed discussions on the papers presented at the end of each session (Bakels, Blong, Driessen, Grattan, Torrence, Riede, Sadori, Vanzetti). Thanks especially go to Jan Driessen for preparing, at short notice, the ‘project SWOT analysis’ around which

the closing discussion focused. Results from this discussion are summarized in the ‘Remarks for future research’. Finally, we thank Martijn van Leusen for chairing the workshop sessions and the closing discussion.

Most of the work of cajoling the authors into submitting and then changing their articles as referees’ reports came in, and of writing this editorial fell to Jan Sevink as Executive Guest Editor for this special issue. He was ably supported by Remco Bronkhorst and by three Guest Editors, each with their specific field of expertise: Martijn van Leusen (archaeology), Mauro Antonio Di Vito (volcanology) and Michael Field (palaeoecology).

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