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^{14}C CHRONOLOGY OF AVELLINO PUMICES ERUPTION AND TIMING OF HUMAN REOCCUPATION OF THE DEVASTATED REGION

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ABSTRACT. The Avellino Pumices eruption was one of the most catastrophic volcanic events of Somma-Vesuvius, which hit prehistoric communities during the Early Bronze Age. In the last 30 yr, several authors reported assessments about its chronology, including radiocarbon datings, but with poor internal agreement and frequently with large experimental errors. A new and more accurate ^{14}C dating of this eruption (1935–1880 BC, 1 σ) was obtained at the CIRCE laboratory in Caserta (Italy) by 3 AMS measurements on a bone sample of a goat buried by the eruption, collected in an Early Bronze Age village at Croce del Papa (Nola, Naples). These results were verified by other measurements on several samples chronologically related to the eruption. Our data show that human resettlement after the eruption occurred rather quickly but lasted only for a short time in areas affected by the volcanic products, like Masseria Rossa and San Paolo Belsito (Nola, Naples), according to ^{14}C dating of archaeological samples collected below and above the eruption deposits. The state-of-the-art chronology of this eruption, emerging from the results obtained in this work as well as from data in the literature, is discussed.

INTRODUCTION

The Avellino Pumices eruption was a catastrophic Plinian event of the Somma-Vesuvius, which occurred in Campania during the Bronze Age and severely affected the pre-protohistoric settlements. It is comparable to the AD 79 volcanic catastrophe, but it had a bigger impact on human settlements, as the eruption clouds headed inland and not towards the sea (Albore Livadie et al. 1997). The Avellino eruption happened after a long period of calmness in volcano activity. In the first phase of the eruption, an imposing tephra column rose up to 36 km in the stratosphere, driven by winds towards the northeast, causing the deposition of pumices, white first and then gray (Rolandi et al. 1993; Albore Livadie et al. 1997). The fallout of gray pumices represents the most intense phase of the eruption. Areas affected by the fallout of pumices are represented in Figure 1a,b. Subsequently, the eruption column partially collapsed, causing the formation of dissolved pyroclastic fluxes that flowed at very high temperature around the eruption center. A big eruption cloud then formed, producing surges going downhill very fast for 25 km, destroying and burying everything on its way.

The Avellino eruption has been intensively studied by geologists, archaeologists, volcanologists, prehistorians, and scientists of other fields, in order to understand what happened to the environment and the prehistoric human settlements after this catastrophic event, which shows a close analogy to the famous AD 79 eruption of Somma-Vesuvius.

Several chronological indications about the approximate date of the eruption were obtained in the last 30 yr, including radiocarbon measurements, as reported by several authors. However, these results were often not in agreement and also showed systematic errors. The reason is that many ^{14}C dates of this eruption were carried out on humic acids or total organic carbon from paleosols, which are subject to substantial age offsets and/or reservoir effects. Moreover, dates obtained from tree trunks indicate the time they were felled and not when they were buried by the pumices. Paleosols overlying eruption products are usually younger than the eruption date but can also be older if the

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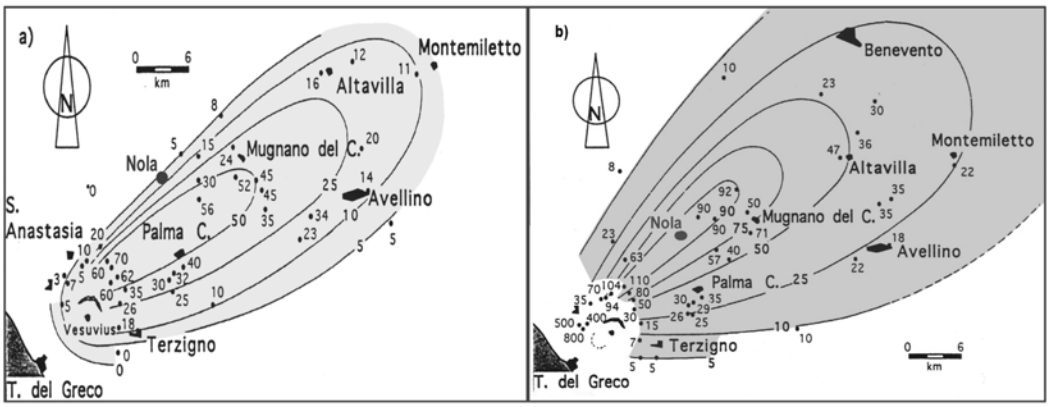


Figure 1 a) Area covered by the white pumices of the Avellino eruption: Nola is in the area border; b) Area covered by the gray pumices of Avellino. Nola is in the area's center.

newly formed soil acquired significant quantities of old carbon. Wood, charcoal, and bone materials are usually more suitable for ^{14}C dating, especially when they were found in sites covered by tephra from the eruption. However, these materials may also have problems, e.g. the choice of samples must be from horizons associated with the eruption itself, without redeposition of old material or contamination sources introduced in the laboratory during the sample preparation procedures.

The first ^{14}C dates on the eruption were carried out in the 1970s, and later in the 1980s and 1990s, by conventional techniques (see Table 1). All these dates come from humic acids in paleosols or from charred tree trunk (Alessio et al. 1973, 1974; Albore Livadie and D'Amore 1980; Delibrias et al. 1986; Marzocchella et al. 1994), because often it was difficult to find other material in sufficient quantity to be dated.

Later, the eruption was dated by the AMS technique on samples like bone, charcoal, seeds, collected in areas around the Somma-Vesuvius (see Table 1). The first ^{14}C dates on short-lived samples, derived from pyroclastic deposits of the eruption and measured by accelerator mass spectrometry (AMS), were obtained by Vogel et al. (1990) (also mentioned in Southon et al. 1994). These AMS dates are based on a plant stem in surge ash coming from a quarry near Pozzelle and on a twig charcoal, from pyroclastic surge and flow deposits which overlie the pumice layer, coming from a quarry near Ottaviano. The two dates (3300 ± 80 BP from the Pozzelle quarry and 3430 ± 50 BP from the Ottaviano quarry) average to 3360 ± 40 BP, (as reported in Vogel et al. 1990), a result younger than the previous dates obtained by conventional techniques.

Terrasi et al. (1994) collected different organic samples in a wide area surrounding the Somma-Vesuvius with the aim to obtain a chronological reconstruction using the AMS technique. The 5 samples from Terzigno (Pozzelle quarry), Ottaviano, Frattaminore, Pratola Serra, and Somma Vesuviana appear to be related to the eruption. The weighted average of 3460 ± 65 BP is in agreement with the results by Vogel et al. (1990), in particular with the date from the Ottaviano quarry.

The excavation campaign in 1995 at San Paolo Belsito revealed 2 skeletons (a man and a woman) found lying on a thick layer of white pumices, with hands covering their face, who died at the beginning of the eruption. The skeleton of this young woman was measured by Terrasi and his colleagues (Albore Livadie et al. 1997) at the Federico II University (Naples). The result, 3560 ± 110 BP, overlaps with the younger average date in Terrasi et al. (1994).

Table 1 Previous ^{14}C ages of the Avellino eruption obtained by conventional techniques and by AMS (*italics*).

Sample code	Sample description	Site	^{14}C age ± 1σ	References
R-830A	Humics from paleosol under Avellino	Pomigliano D'Arco	3510 ± 50	Alessio et al. 1973
R-830B	Humics from paleosol under Avellino	Pomigliano D'Arco	3610 ± 50	Alessio et al. 1973
R-938	Humic acids from paleosol underlying the AD 79 Plinian eruption and overlying prehistoric pumice	Cava dell' Arciprete 2	3870 ± 50	Alessio et al. 1974
Gif-4517	Paleosol from Palma Campania (47)	Palma Campania	3760 ± 70	Albore Livadie and D'Amore 1980
Gif-5264	Paleosol between pumices of Pompei and Avellino	Cava Primavera, PFSV 300	3530 ± 70	Delibrias et al. 1986
Gif-4486	Paleosol underlying pumice	Terzigno, PFSV 156	3600 ± 80	Delibrias et al. 1986
Gif-4517	Paleosol under Avellino pumice	Astroni, PSFV 210	3760 ± 70	Delibrias et al. 1986
Rome 1775	Charred tree trunk	Sarno	3660 ± 45	Marzocchella et al. 1994
Rome 1776	Charred tree trunk	Sarno	3615 ± 45	Marzocchella et al. 1994
RIDDL-1338/1343	Average from plant stem in surge ash and twig charcoal above pumice	Pozzelle and Ottaviano quarry	*3360 ± 40*	Vogel et al. 1990; Southon et al. 1994
	Average from burned vegetation, charcoal and animal bone	Five sites involved by the eruption	*3460 ± 65*	Terrasi et al. 1994
	Skeleton of a woman, died during the eruption	San Paolo Belsito	*3560 ± 110*	Albore Livadie et al. 1997
	Charcoal	Ottaviano	*3548 ± 129*	Rolandi et al. 1998
	Abies seed overlying the TM-4 tephra (correlated to Avellino eruption) in Monticchio Lake	Lago grande di Monticchio (Basilicata)	*3920 ± 50*	Watts et al. 1996

Another date, 3548 ± 129 BP (Rolandi et al. 1998), was obtained on small pieces of charcoal collected in Ottaviano interbedded in the underlying paleosol. This result is in good agreement with the previous date (Albore Livadie et al. 1997) and also overlaps with the younger average in Terrasi et al. (1994) and with the younger date from Ottaviano in Vogel et al. (1990).

Finally, an AMS measurement (Watts et al. 1996) on a seed overlying the TM-4 tephra in the Lago Grande di Monticchio, located 120 km east of Naples in the Monte Vulture volcanic complex in the Basilicata region, gave an age of 3920 ± 50 BP, which is older than all previous results. Some reviews quote 3590 ± 25 BP (Andronico et al. 1995) and 3675 ± 57 BP (Wulf et al. 2004—an average from Alessio et al. 1973; Delibrias et al. 1979; Vogel et al. 1990; Andronico et al. 1995; Di Vito et al. 1998; Rolandi et al. 1998).

Considering all the dates published until now, we have a wide range for the Avellino eruption between 3.3 and 3.9 kyr BP. We can take the ^{14}C age by Watts et al. (1996) as the maximum age. Concerning the minimum age, an indication may be obtained from the younger protohistoric erup-

tions, as well as from human resettlement after the Avellino eruption. At least 6 main eruptions (AP1-AP6) of Vesuvius occurred between the Avellino and Pompei (AD 79) eruptions, with some additional minor events (Rolandi et al. 1998; Andronico et al. 1995; Andronico and Cioni 2002; Insinga et al. 2007). In this article, we consider the first 2 eruptions (AP1 and AP2), classified as sub-Plinian to phreato-Plinian events. The ^{14}C ages of these 2 eruptions, both from the literature and our own research, are shown in Table 2. Concerning the AP1 protohistoric eruption, only 1 of 3 measurements obtained by us is reported at this stage of the results.

Table 2 Previous ^{14}C ages associated with the first 2 protohistoric eruptions (AP1, AP2) that occurred after the Avellino eruption. In *italics*, 2 of several results obtained in this work (Figure 4).

	Sample description	^{14}C age ±1 σ	References
1st Protohistoric (AP1)	Charcoal interbedded in the products of the eruption or in the underlying paleosols	3500 ± 60 3480 ± 60 3279 ± 60	Rolandi et al. 1998
	Charcoal from humic surface on ash beds of the final phase of Avellino	3220 ± 65	Andronico et al. 1995
	Animal bone collected above AP1	*3399 ± 37*	CIRCE laboratory
2nd Protohistoric (AP2)	Charcoal interbedded in products of the eruption or in underlying paleosols	3280 ± 70 3250 ± 70 3150 ± 100	Rolandi et al. 1998
	Animal bone collected above AP2	*3380 ± 23*	CIRCE laboratory

In our research, new ^{14}C dates from the Avellino eruption were obtained by an animal bone sample, found in an Early Bronze Age village, which was hit and buried by the eruption. This bone sample from a goat was treated and measured at the CIRCE AMS laboratory (Terrasi et al. 2007). Special attention was paid in the phases of sample preparation (particularly in the chemical treatment) to eliminate contaminants introduced after sample death. Moreover, the ^{14}C dates on the bone from a goat are supported by other dates of findings before and after the Avellino eruption.

STUDY SITES

Several settlements with clear stratigraphic connections to the eruption were studied and investigated. In particular, in this work we have considered sites below and above this event and a site buried by the eruption.

Croce Del Papa: An Early Bronze Age Village Buried by the Eruption

In May 2001, the discovery of 3 huts found 6 m below ground level, in the immediate outskirts of Nola (Naples), highlighted an early Bronze Age village, perfectly preserved and buried by the products of the Avellino eruption (Albore Livadie and Vecchio 2005; AA.VV. 2002). These huts were originally part of a larger village, with ovens, a pen with 9 pregnant goats, and other enclosures separating animals from the domestic areas. The interest of this excavation is in the conditions of preservation due to the local conditions of the eruption. In fact, after the fall of gray pumices, the pumices accumulated outside the huts, without causing their collapse. Then, abundant rainfall occurred, together with the fallout of ash, which covered the roofs without causing their collapse, but penetrated like thin depositions within the huts. These rainfalls brought produced a wave of mud that penetrate slowly within the structures and caused the collapse of the huts inwards, allowing their preservation (see Figure 2a). As we can see in Figure 1a, the Nola area was only marginally hit by

white pumices during the first hours of the eruption. Therefore, the inhabitants had the time to run away at the beginning of the eruption. In fact, the footprints of the fugitives, together with the hoof marks of the domestic animals, are very clearly visible at this site (see Figure 2b).

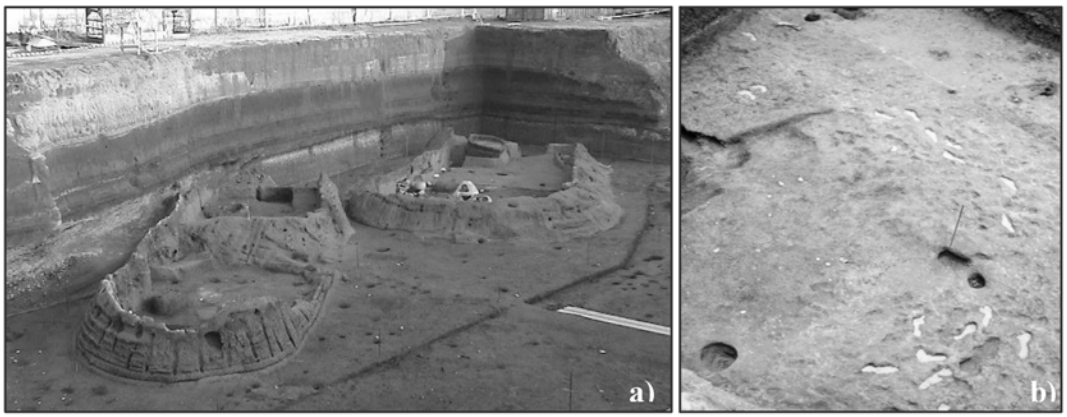


Figure 2 a) 2 of the 3 huts found in the Bronze Age village at Croce del Papa (Nola, Naples): a wave of mud penetrated slowly within the structures, enabling their preservation. b) Human footprints and hoof marks of domestic animals on the paleosurface.

Evidence of Human Occupation Before and After Avellino

Recent archaeological excavations during 2001 found evidence for a rapid return of some human groups, who settled on top of the pumice deposits from the Avellino eruption. Previously, it had been assumed that the inhabitants, living E-NE of Somma-Vesuvius, i.e. in the prevalent direction of the fallout deposits, did not have a chance to escape. However, at Masseria Rossa (MR) (AA.VV. 2002) a few km away from the Croce del Papa site, remains of huts were discovered just above the pumice eruption deposits. Only 1 hut was partially investigated, which had a constructive typology similar to Croce del Papa and whose pottery resembled the typologies of the Palma Campania culture. A human skull was discovered and collected in the investigated hut (US24) at Masseria Rossa.

This discovery highlighted other findings, like the traces of human presence relative to a hut above the Bronze Age cemeteries, covered by the Avellino pumices, at San Paolo Belsito (SPBS) in the Monticello site. A bone sample was collected at Monticello from a ditch related to a hut above the pumice eruption, as well as charcoal derived from a paleosurface of the same hut.

Archaeological excavations were conducted in 1984 and 1988 at La Starza, close to the modern town of Ariano Irpino (Avellino), by an interdisciplinary group directed by the archaeologist Claude Albore Livadie. Some huts were uncovered above the Avellino pumices, indicating a transition stage between the Early Bronze Age and the Middle Bronze Age, i.e. a transition stage between the Palma Campania and the Protoappenninico B cultures (Albore Livadie 1991–1992; Talamo 1996a). Some charcoal samples, coming from these structures above the Avellino pumices and corresponding to different stratigraphic units (US), were collected.

Other information came from the settlement at Palma Campania (NA) (Albore Livadie and D'Amore 1980; Albore Livadie 1994; Talamo 1998c), which gave its name to the culture of the Early Bronze Age in Campania. Here, remains of a hut were discovered below the pumice deposits from the Avellino eruption. Human resettlement above the Avellino pumices was uncovered at the site of Piazzale Tecchio in Naples (Vecchio et al. 2007). Concerning the Palma Campania settlement, we collected charcoal from a layer of soil mixed with ashes and charcoal, which covered the

floor of a hut abandoned just before the area was covered by the eruption. This unit was covered by a thin soil layer, which testifies to the use of this area for farming purposes after the abandonment of the oldest settlement, existing before the settlement covered by the eruption. Concerning Piazzale Tecchio, the discovery of sequence of the holes, corresponding to piles of huts, confirmed a human resettlement above the Avellino pumices. This sequence is not as clear as in the San Paolo Belsito site (see below), but according to the pottery the settlement, seems to belong to the Protoappenninico culture. In order to investigate the timing of this resettlement, a charcoal sample from Piazzale Tecchio was collected and measured.

San Paolo Belsito: A Clear Stratigraphic Sequence of Human Occupation Frequentation Since the Pre-Avellino Eruption Until the 2nd Protohistoric Eruption

Building activities in 2006 during construction of a private house revealed the first inhabited level linked to a settlement above the 1st and 2nd protohistoric eruptions (AP1 and AP2), which occurred after the Avellino volcanic event. Further excavations here uncovered a clear stratigraphic sequence of site occupation from the period before the Avellino eruption until the soil level above AP2. There is clear evidence of anthropogenic activities, and marks found on the soil suggest usage of this area for farming purposes. Animal bones together with pottery of Palma Campania and Protoappenninico cultures were found at this site. Several animal bones were collected just below and above the Avellino eruption and just above the AP1 and AP2 eruptions, in order to investigate the chronology of these occupation strata.

METHODS

Bone, charcoal, and wood samples were collected in layers below and above the volcanic products in several archaeological sites covered by the eruption. In particular, to date the eruption, bone from a pregnant goat killed and buried by the eruption, from the animal pen found in the Croce del Papa village, was collected. To obtain a reliable measurement, the contaminants introduced after the goat died and was buried were eliminated using physical and chemical treatments. After examining the sample and physical cleaning of external contaminants, like roots and soil, the bone was crushed and the powder underwent a chemical treatment. In this research, a scrupulous study on different bone chemical treatments was carried out, with the aim to remove contaminants that may distort the dating from the extracted carbon fraction (in this case, collagen). The goat bone used for ^{14}C dating was chemically treated with 3 different preparation methods: 1) the Longin method (Longin 1971); 2) the Longin method modified with the addition of NaOH, to remove humic contaminants (both methods carried out at the CIRCE laboratory in Caserta); and 3) the ultrafiltration method (Bronk Ramsey et al. 2004) carried out at the Research Laboratory for Archaeology and the History of Art at Oxford. The other bone samples were treated with the Longin method modified with the addition of NaOH or with the ultrafiltration method of the Oxford laboratory. For charcoals and woods, the AAA (acid-alkali-acid) protocol was used (Mook and Streurman 1983). After the chemical pretreatment, the CO_2 was produced in a muffle oven at 920 °C for 6 hr, inside a sealed quartz tube, and then purified in a cryogenic line. The purified CO_2 was converted to graphite by the Bosch reaction (Vogel et al. 1984) in a multisample graphitization line controlled by a LabView interface (Passariello et al. 2007). The graphite samples were pressed into aluminum cathodes and measured by the CIRCE high-precision AMS system (Terrasi et al. 2007, 2008; Marzaioli et al. 2008). The obtained ^{14}C ages were calibrated using the OxCal program (Bronk Ramsey 1995, 2001) and the IntCal04 calibration curve data (Reimer et al. 2004).

RESULTS

^{14}C dates obtained in this work are given in Table 3 of all samples collected in several sites with clear associations to settlements below and above the volcanic products of the Avellino eruption.

Table 3 All ^{14}C ages obtained in this work, which enclose the period from below Avellino to above Avellino.

CIRCE code	Site	Sample name/ material	^{14}C age ±1 σ	Calibrated age (BC, 1 σ)	Calibrated age (BC, 2 σ)
DSH:138	Palma Campania (NA)	US27>/charcoal	3666 ± 52	2140–1960	2200–1900
DSH:161	San Paolo Belsito (Nola, NA)	US45/animal bone	3597 ± 22	2010–1915	2030–1890
Avellino eruption	Croce del Papa (Nola, NA)	Goat	3550 ± 20	1935–1880	1960–1770
DSH:153	San Paolo Belsito (Nola, NA)	US30/animal bone	3513 ± 20	1890–1770	1900–1750
DSH:143	Masseria Rossa (Nola, NA)	US24/human skull	3492 ± 23	1880–1770	1890–1740
DSH:142	San Paolo Belsito (Nola, NA)	US6/charcoal	3465 ± 19	1880–1740	1880–1690
DSH:156	San Paolo Belsito (Nola, NA)	US25/animal bone	3426 ± 48	1870–1640	1890–1620
DSH:76	La Starza di Ariano Irpino (AV)	US633L/charcoal	3466 ± 20	1880–1740	1880–1690
DSH:77	La Starza di Ariano Irpino (AV)	QB5-US203b/charcoal	3423 ± 25	1750–1685	1870–1630
DSH:78	La Starza di Ariano Irpino (AV)	QC3-US629/charcoal	3470 ± 24	1880–1740	1890–1690
DSH:105	San Paolo Belsito (Nola, NA)	US150/animal bone	3361 ± 20	1685–1625	1740–1600
DSH:160	San Paolo Belsito (Nola, NA)	US150/animal bone	3368 ± 47	1740–1610	1770–1520
DSH:159	San Paolo Belsito (Nola, NA)	US150/animal bone	3399 ± 37	1750–1640	1880–1600
DSH:154	San Paolo Belsito (Nola, NA)	US85/animal bone	3380 ± 23	1730–1630	1740–1620
DSH:53	Piazzale Tecchio (NA)	US264</charcoal	3368 ± 19	1690–1630	1740–1610

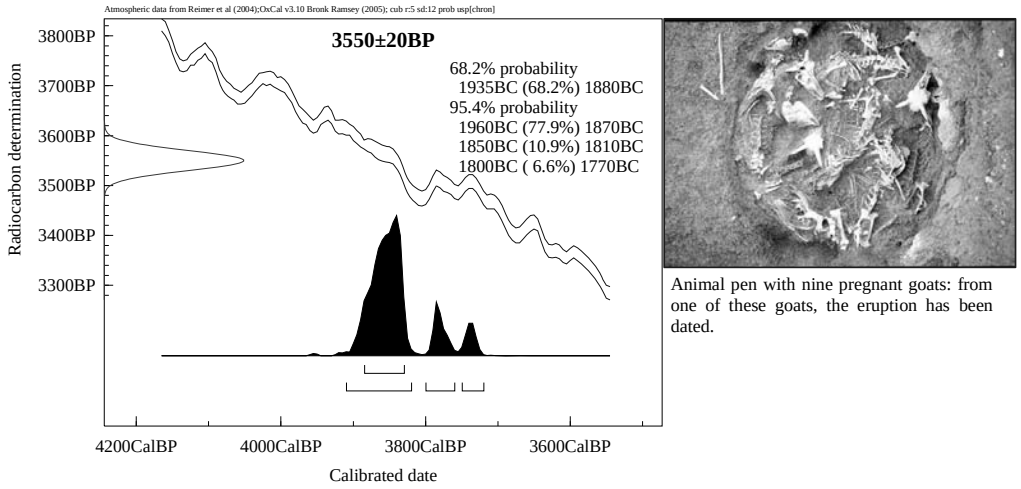
The 3 ^{14}C ages obtained, following different chemical treatments of the investigated goat bone collected at Croce del Papa, agree well with each other, as shown in Table 4.

Table 4 ^{14}C ages of a goat bone of Croce del Papa, chemically treated at the CIRCE and Oxford laboratories and measured at the CIRCE AMS laboratory. The different chemical treatments gave ^{14}C dates in excellent agreement with each other.

CIRCE code	Sample description	Site	^{14}C age ±1 σ
DSH 145	Goat bone	Animal pen at Croce del Papa (Nola)	3558 ± 20
DSH 103			3560 ± 20
DSH 146			3533 ± 22

The date for the Avellino eruption, according to the average of the 3 ^{14}C dates in Table 4, is 3550 ± 20 BP. We have taken the smallest of the 3 uncertainties (±20 yr) as representative of the accuracy of the result, because the weighted average error (±12, calculated with R_Combine in OxCal; Bronk Ramsey 2001) could lead to an underestimation: indeed, the 3 measurements were obtained by nor-

malization to the same standard and this introduces a correlation among the different determinations, which is not taken into account in the weighted average uncertainty. This new ^{14}C date (3550 ± 20 BP) provides the most accurate dating of the Avellino eruption obtained until now, giving a narrow calibrated date of the eruption: 1935–1880 BC (1 σ), see Figure 3.



Animal pen with nine pregnant goats: from one of these goats, the eruption has been dated.

Figure 3 ^{14}C age of the goat sample collected in the Early Bronze Age village at Croce del Papa, calibrated using atmospheric data from Reimer et al. (2004) and OxCal v 3.10 software (Bronk Ramsey 1995, 2001).

In Figure 4, we show the ^{14}C ages of samples collected below and above the Avellino eruption and from above the first 2 protohistoric eruptions (AP1, AP2) at San Paolo Belsito, together with the results for the Avellino eruption presented in this paper. These data provide constraints (upper and lower) to the Avellino eruption. Moreover, they show that human resettlement after the Avellino disaster took place within a short time, not after a long period, as suggested previously. The protohistoric eruptions occurred one after another, about 200 yr after the Avellino cataclysm. These protohistoric eruptions were not catastrophic, so the inhabitants did not leave the settlement during and after these events.

DISCUSSION

In comparison to other ^{14}C dates of the Avellino eruption obtained in the last 20 yr, principally on paleosols, humic acids or charcoals fragments found in pyroclastic deposits, we used a short-lived sample collected from a village that was indubitably buried by the eruption. All procedures of sample preparation were optimized to eliminate possible contaminants introduced to the goat bone after its death (chemical phase) and minimizing the sample contamination during the combustion and graphitization phases. Moreover, the CIRCE AMS system allows a statistical precision <0.3% on measurements, corresponding to an error of 20–25 yr on ^{14}C dates. The isotopic ratios of samples were measured in several batches with respect to the IAEA C3 cellulose standard.

Croce Del Papa Result and Comparison with Previous Measurements

In Figure 5, we compare the results from Croce del Papa with other ^{14}C dates performed in the last 10 yr, obtained by the Naples group using the AMS system of Naples (in Terrasi et al. 1994 and Albore Livadie et al. 1997, shown before in Table 1).

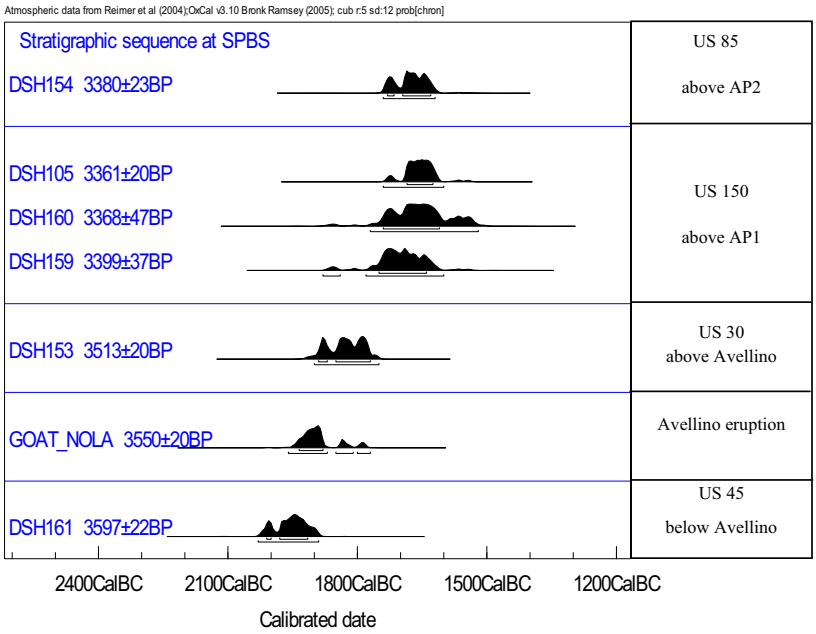


Figure 4 Calibration of the ^{14}C ages obtained from bone samples collected in stratigraphic units below and above the Avellino deposits and above the AP1 and AP2 protohistoric eruption layers at San Paolo Belsito (calibrated with OxCal v 3.10 Bronk Ramsey [1995, 2001], data from Reimer et al. [2004]). It shows how Avellino is well "bracketed."

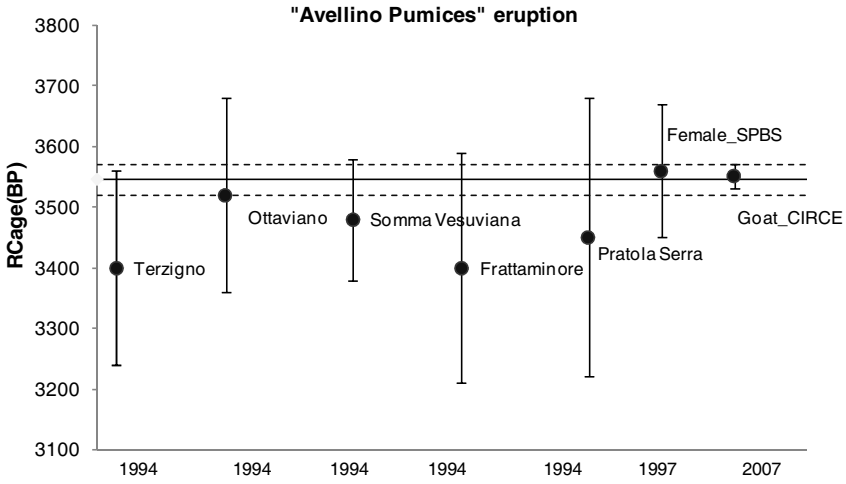


Figure 5 Comparison between the result obtained in our present research and other ^{14}C dates obtained by the Naples group (see Table 1). The continuous horizontal line represents the weighted average obtained on all results (except the Terzigno sample). The results are in agreement within the experimental error margins.

All ^{14}C dates come from samples of burnt vegetation, charcoal, and bones collected in sites around the Somma-Vesuvius. The samples Terzigno, Ottaviano, Frattaminore, Pratola Serra, and Somma Vesuviana are specifically the 5 ^{14}C ages presented in Terrasi et al. (1994), which we reported here with weighted averages in Table 1. The sample Female_SPBS represents the bone of a woman found

at San Paolo Belsito (discussed in the Introduction), who died during the eruption. The pregnant goat at Croce del Papa is indicated as Goat_CIRCE sample. The continuous horizontal line represents the weighted average of 3545 ± 19 BP, obtained on all samples, excluding the Terzigno sample from the average (explained below). The ^{14}C ages obtained by the Naples group (Terrasi et al. 1994; Albore Livadie et al. 1997) and the CIRCE group (this paper) are mutually in agreement within the experimental errors. Moreover, the Goat_CIRCE sample reduced the probability interval of the eruption.

Rolandi et al. (1998) claim that "the sample collected at Pozzelle quarry (Terzigno) (Vogel et al. 1990; Southon et al. 1994; Terrasi et al. 1994) is not related to the Avellino eruption. Stratigraphic investigation probably indicates a protohistoric eruption." The date of the eruption, based on Vogel et al. (1990) and Southon et al. (1994), is a weighted average of 2 dates: 3300 ± 80 and 3430 ± 50 BP. The first ^{14}C age from Pozzelle (3300 ± 80 BP) is in agreement with the dates at San Paolo Belsito of the protohistoric eruptions (3361 ± 20; 3368 ± 47; 3369 ± 16; 3399 ± 37 BP; obtained in our research). Moreover, the Terzigno date (3400 ± 160 BP) in Terrasi et al. (1994) also agrees with the above results and is excluded in the present investigation in relation to the Avellino eruption. However, the dates from Ottaviano, 3430 ± 50 and 3520 ± 160 BP (in Terrasi et al. 1994) and 3548 ± 129 BP (in Rolandi et al. 1998) are in agreement with each other in relation to the Avellino event. Following these considerations and the new result obtained in this research on the Avellino eruption date, we have prepared Table 5, where we have only put the ^{14}C age of 3430 ± 50 BP (Ottaviano) for Vogel et al. (1990). Here, 3473 ± 73 BP represents the new weighted average (without the Terzigno sample) for Terrasi et al. (1994) and 3550 ± 20 BP is the result obtained in our investigation.

Table 5 Previous ^{14}C ages of the Avellino eruption obtained by AMS, presented in Table 1, in the light of the results and reflections in this paper, with the addition of new ^{14}C ages obtained in our research.

Sample description	Site	^{14}C age ±1 σ	References
Twig charcoal above pumices	Ottaviano quarry	3430 ± 50	Vogel et al. 1990; Southon et al. 1994
Average from burned vegetation, charcoal and animal bone (except Terzigno)	4 sites involved in the eruption	3473 ± 73	Terrasi et al. 1994
Skeleton of a woman, died during the eruption	San Paolo Belsito	3560 ± 110	Albore Livadie et al. 1997
Charcoal	Ottaviano	3548 ± 129	Rolandi et al. 1998
Abies seed overlying the TM-4 tephra (correlated to Avellino eruption) in Monticchio Lake	Lago grande di Monticchio (Basilicata)	3920 ± 50	Watts et al. 1996
Pregnant goat	Croce del Papa (Nola)	3550 ± 20	This work

The ^{14}C ages in Table 5 are better emphasized in Figure 6. The date 3550 ± 20 BP (present work) is in agreement with the dates in Terrasi et al. (1994), Albore Livadie et al. (1997), Rolandi et al. (1998), and within 2 σ of the dates in Vogel et al. (1990) and Southon et al. (1994).

Considering the new results obtained in our investigation, in which several samples collected below and above the eruption deposits were measured, we can conclude that the date by Watts et al. (1996) is too old, as compared to all other dates.

Human Life Before and After Avellino

The measurement on the Palma Campania site (see code DSH:138 in Table 3) confirms its anteriority with respect to Avellino and places the Palma Campania culture in the early 20th century BC,

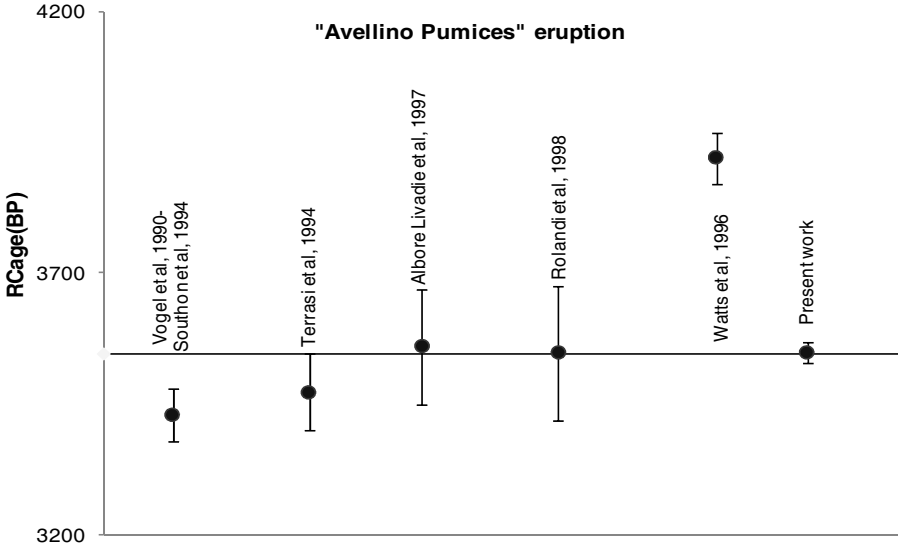


Figure 6 Comparison of all results obtained in previous and present studies on the Avellino eruption (see Table 5). The continuous horizontal line is related to the results from our present research. The results are in agreement within 1 σ or 2 σ, except for the date by Watts et al. (1996).

that is, until now, the most ancient indication in Campania. The Avellino eruption represents somehow the end of this culture, even if it is not so clear cut. In fact, even if the "life" of sites affected by the pumice deposition almost completely ended just after the eruption, our results show that the anthropogenic resettlement in areas not covered by pumice during the first hours of the eruption—such as Masseria Rossa (Nola) (see code DSH:143 in Table 3) and San Paolo Belsito (Nola) (see codes DSH:153, 142, 156 in Table 3), both situated close to the Early Bronze Age village at Croce del Papa—occurred rather quickly but lasted only for a short time. Moreover, they show pottery similar to the typologies of the Palma Campania culture. We noticed settlement continuity during the entire Bronze and Iron ages in just a few sites that were covered only by volcanic ashes, but not by pumice, such as La Starza di Ariano Irpino. The results obtained (see code DSH:76, 77, 78 in Table 3) give further suggestions on the human resettlement after Avellino and important indications about the transition between the Palma Campania and the "Protoappenninico B" cultures.

Unfortunately, over the years, the activity of a quarry has destroyed much of the hill in La Starza, which represents a long-lasting human occupation in Campania (from the Neolithic to the Iron Age). However, the settlements from the Protoappenninico culture to the final stage of Bronze Age still allow to fill many of the gaps in the region. In fact, there was a long break in settlement occupation in the area covered by the eruption during the early Middle Bronze Age, characterized by the Protoappenninico culture (Middle Bronze 1, 2: ~16–15th centuries BC), except in San Paolo Belsito (as discussed earlier, where clear signs of this culture are present).

The situation in the Afragola site is also significant. The site is characterized by several settlements belonging to the Palma Campania culture, destroyed by the Avellino eruption, where human resettlement after the eruption only took place in the Late Bronze Age (Nava et al. 2007). This occupation gap is not present outside the affected area. In the area covered by products of the eruption, the renewal of the natural environment happened quickly (Albore Livadie et al. 2001). Though the renewal of the vegetation and ecology provided ideal conditions for human repopulation with a partial resettlement during the Protoappennico culture (Albore Livadie et al. 2007), a full reoccupation

in the "pumices" area took place only in the advanced phase of the Middle Bronze Age, characterized by the Appenninico classico culture (Middle Bronze 3, 15–14th centuries BC), which represents the last phase of a clear prehistoric occupation (Talamo 1998b). Finally, the result at Piazzale Tecchio (see code DSH:53 in Table 3) is consistent with the results at San Paolo Belsito (see codes DSH:105, 160, 159, 154 in Table 3), suggesting that the settlement is coeval with a phase covered by 1 of the 2 protohistoric eruptions at San Paolo Belsito.

CONCLUSIONS

To obtain new ^{14}C dates of the Avellino eruption, we have used short-lived samples collected from several sites related stratigraphically to the volcanic deposits of the eruption. We paid particular attention to a number of research aspects: a) the context-event relationship; b) sample preparation and scrupulous care in bone chemical pretreatment; c) intercomparison with other laboratories; d) experience in other laboratories; e) an AMS system that allows high-precision (<0.3%) ^{14}C dating. Thus, we obtained a new average ^{14}C date for the eruption of 3550 ± 20 BP, giving a calibrated age of 1935–1880 BC (1 σ). This date is supported by ^{14}C ages of findings belonging to the periods *ante quem* and *post quem*, as the anthropogenic resettlement and the protohistoric eruptions happened after the Avellino eruption. All results obtained in this work, calibrated by OxCal program (Bronk Ramsey 1995, 2001) are shown in Figure 7. All these dates provide further chronological constraints (upper and lower) to the Avellino eruption.

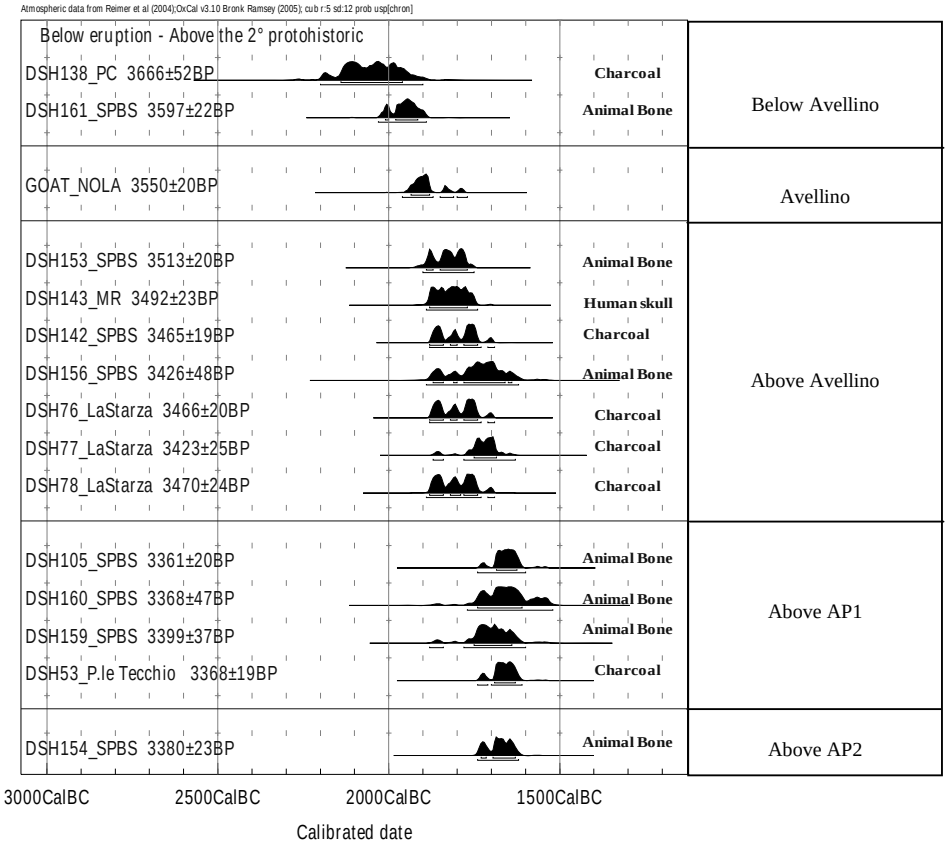


Figure 7 Calibration of ^{14}C ages obtained in this work, coming from several samples collected below and above the Avellino deposits and above the first 2 protohistoric eruptions in sites affected by the eruption.

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