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The 346 A.D. earthquake (Central-Southern Italy): an archaeoseismological approach

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Abstract
The 346 A.D. earthquake is known through sparse historical sources. It is mentioned by Hyeronimus as felt in Rome and responsible for damage in the ancient Campania Province. Four epigraphs report the earthquake as the cause for the restorations of buildings at Aesernia-Isernia, Allifae-Alife, Telesia-Telese and Saepinum-Sepino. On this basis, an area possibly struck by the earthquake was already defined in the literature. Another seventeen epigraphs mentioning restoration or re-building of edifices in localities of central-southern Italy (without explicitly referring to the earthquake as the cause of the damage) are possibly related to the earthquake effects. We tried to enhance our knowledge on the 346 earthquake through archaeoseismological analyses. The investigation has benefited from specific fieldwork during archaeological excavations and a critical review of the available archaeological literature. However, a correct archaeoseismological interpretation is hindered by the occurrence of two earthquakes (346 and 375 A.D.) in a short time span and in adjacent areas (whose effects may be archaeo-chronologically undistinguishable) and the not always univocal evidence of the seismic origin of the detected collapses or restoration of structures. For this reason we propose a representation of the 346 A.D. effects through two extreme pictures: 1) the localities for which conclusive data on the earthquake effects are available and 2) the data of point 1 plus the localities for which archaeoseismological data consistent with the earthquake are available. The latter view defines an area of possible damage related to the 346 event larger than that previously known. In particular, the earthquake damage may result from a seismic sequence similar to that, which struck a part of the central and the southern Apennines in 1456, or from an event comparable to that which occurred in 1805, responsible for widespread damage in the northern sector of the southern Apennines.

Key words *346 A.D. earthquake – archaeoseismology*

1. Introduction

The recurrence interval per seismogenic source (large magnitude earthquakes) in peninsular Italy is generally longer than 1000 years (*e.g.*, Pantosti *et al.*, 1993 and 1996; Galadini and Galli, 1999; D'Addezio *et al.*, 2001). The Italian catalogues report earthquakes which occurred in a long time span (*e.g.,* 461 B.C. - 1990 A.D., Boschi *et al.*, 1997). However, the historical data on the earthquake effects are generally sparse at least until the 13-14th century events (*e.g.,* Stucchi and Albini, 2000). Recurrence intervals and the characteristics of the historical data suggest that many large faults which produced destructive earthquakes in modern times may have previously been activated during a period of scarce historical information.

An increase in the knowledge of the damage related to ancient earthquakes may derive from archaeoseismology. In the Italian area, in particular, the largest amount of archaeological infor-

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mation is available for a period between the 1st century B.C. and the 4th-5th century A.D. Therefore, particularly in this chronological interval, archaeology can give data on structure collapses, abandonments, restorations possibly related to strong earthquakes.

The 346 A.D. earthquake is a typical destructive event for which a scarcity of the historical sources prevents a reliable definition of damage distribution. For this reason we tried to improve the knowledge on the earthquake effects by means of archaeoseismological data. One of the purposes of the research is understanding if the 346 event is comparable (in terms of damage distribution) to one of the destructive earthquakes which affected central-southern Italy in more recent times (*e.g.,* the 1349, 1456, 1688, 1805 earthquakes; Working Group CPTI, 1999).

This paper deals with archaeoseismological investigations on the 346 A.D. earthquake. After a section dedicated to a description of the historical sources, we will describe the archaeological data available for numerous sites in the area presumably affected by the earthquake. We adopted an «areal» approach, through the correlation of the evidence of destruction (and/or consequent restorations/rebuildings) approximately related to the same time span at different sites. The archaeoseismological data define a picture of localities possibly damaged by the earthquake. However, we will show that several issues hinder the definition of a reliable picture of the coseismic effects. In the discussion we propose a possible solution to give a more effective representation of the earthquake.

2. Previous knowledge on the 346 A.D. earthquake

As reported in the introduction, the 346 A.D. earthquake struck an area which, more recently, has been affected by earthquakes with $M > 6$ (*e.g.,* the 1349 and 1456 sequences, the 1688 and 1805 events; fig. 1a-d). This conclusion can be derived from a comparison between the 346 earthquake effect area (available from Guidoboni, 1989 and Guidoboni *et al.*, 1994) and the damage distribution of the above mentioned earthquakes (figs. 1a-d, 2). However, the comparison of the two figures does not permit us to conclude that the 346 A.D. earthquake represents a sort of «ancient analogue» of one of the modern events represented in fig. 1a-d. This is due to the fact that the 346 earthquake area can be defined from too few independent sources, as indicated by Guidoboni (1989) and Guidoboni *et al.* (1994).

As reported by the above mentioned authors, an earthquake in the Campania «province» is mentioned by Hyeronimus (4th-5th century A.D.) in the Chronicon (translation and update of the Chronicon by Eusebius of Caesarea): *«Dyrrachium terrae motu corruit et tribus diebus ac noctibus Roma nutavit plurimaeque Campaniae urbes vexatae»* («Durrës ruined by an earthquake, for three days and three nights Rome was shaken and numerous towns in Campania were struck»). Since it is difficult to admit that the same earthquake destroyed localities in Albania (Durrës) and Italy (Rome and the Campania region), it is evident that the above reported sentence is related to two different seismic events, which probably occurred in a short time span (Guidoboni, 1989). As indicated by Guidoboni (1989), different dates of the earthquake have been proposed in the historical literature. The widely used date of 346 A.D. has been attributed to the earthquake by Mazzarino (1973), based on the reading of Hyeronimus. Moreover, this date is consistent with the probable age of composition (346 A.D.) of «De Errore Profanarum Religionum» by Julius Firmicus Maternus (4th century A.D.) (Guidoboni, 1989). In his treatise, Maternus reports general information about the earthquakes which affected the earth at that time: *«timorem suum assidui motus tremoribus confitetur»* («the earth reveals its dread through the frequent earthquakes»).

After the administrative reform of the Roman Empire promoted by Diocletian (284-305 A.D.), part of the Samnium (the region of southern Italy which probably suffered the most significant damage, see below) was part of the Campania Province. In the mid 4th century A.D., the Samnium became an independent province. According to some authors (*e.g.,* Camodeca, 1972; De Benedittis, 1988), the administrative change was possibly aimed at bet-

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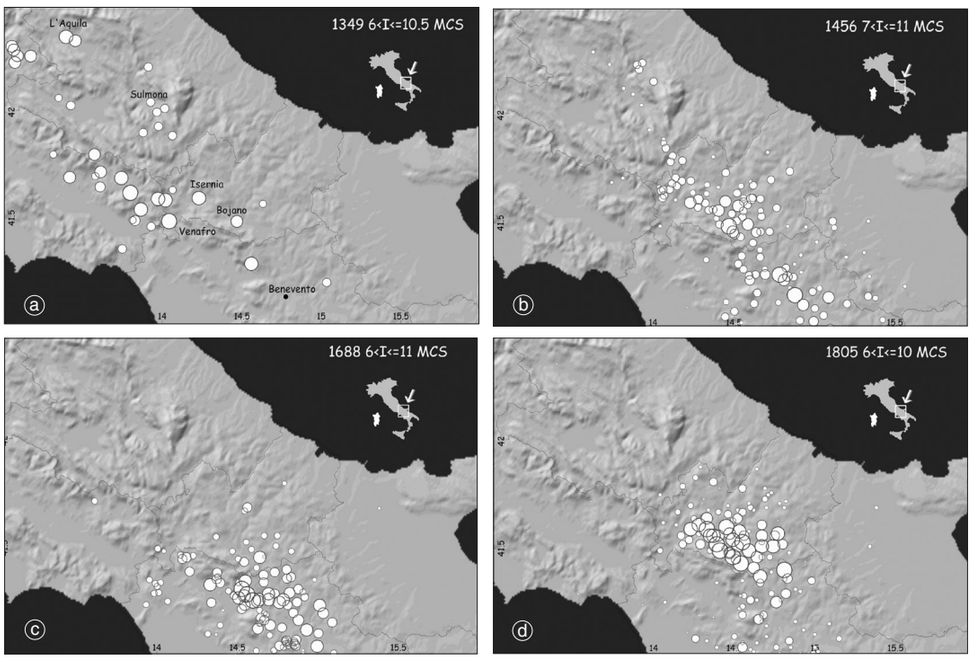

Fig. 1a-d. Damage distribution related to the main historical earthquakes which struck the investigated region. a) 1349 earthquake sequence; b) 1456 earthquake sequence; c) 1688 earthquake; d) 1805 earthquake. The damage distributions have been derived from Boschi *et al.* (1997), for the 1688 and 1805 earthquakes and from Monachesi and Stucchi (1998) for the 1349 and 1456 earthquakes. The intensity datapoints have been plotted on a 1:250 000 scale DEM based on topographic data by Istituto Geografico Militare (Florence, Italy).

ter addressing public intervention in the area struck by the earthquake. If this is true, the earthquake effects were severe.

Information traditionally related to the 346 earthquake can also be derived from epigraphs (see the Appendix for the texts). Guidoboni (1989) reported three epigraphs (Isernia-Aesernia, Alife-Allifae, Telese-Telesia, see fig. 2 for location) mentioning the earthquake as the cause for restorations promoted by *rectores* (governors) of the province (Fabius Maximus and Autonius Iustinianus). The word «earthquake» is clearly present in two of these epigraphs (CIL IX 2338 from Allifae and CIL IX 2638 from Aesernia, the former no longer available). In the other epigraph (from Telesia, in a private collection), «earthquake» («*terraemotus*» in Latin) can be derived from the suffix «-*tus*» (Camodeca, 1972). Moreover, in the epigraph from Aesernia (CIL IX 2638, reporting restorations of the market under the governor Autonius Iustinianus) the word «earthquakes» («terraemotibus») has been used. We do not know if the use of the plural indicates that the 346 earthquake is actually a seismic sequence or if the restorations became necessary after the occurrence of a number of earthquakes during a relatively long time span (Guidoboni, 1989; Cappelletti, 1999).

More recently, another epigraph (from Saepinum) mentioning the earthquake as the cause of restorations has been published by Buonocore (1992) and reported in the «Catalogue of ancient earthquakes in the Mediter-

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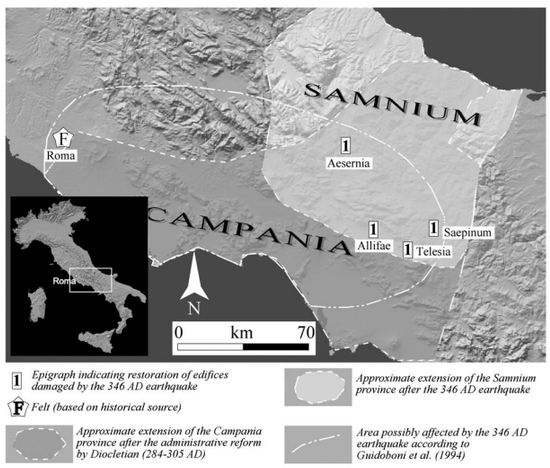

Fig. 2. Available historical data on the 346 A.D. earthquake (epigraphs and the Chronicon by Hyeronimus, 4th-5th century A.D.), reported in Guidoboni (1989) and Guidoboni *et al.* (1994). The approximate extension of the Campania province formed after the administrative reform by Diocletian (284-305 A.D.) is reported (*e.g.,* Cantarelli, 1901), together with the extension of the Samnium province, formed after the 346 A.D. earthquake (as derived from De Benedittis, 1988). The Campania province is the area to which damage can be generically related, based on Hyeronimus (see text for further explanation).

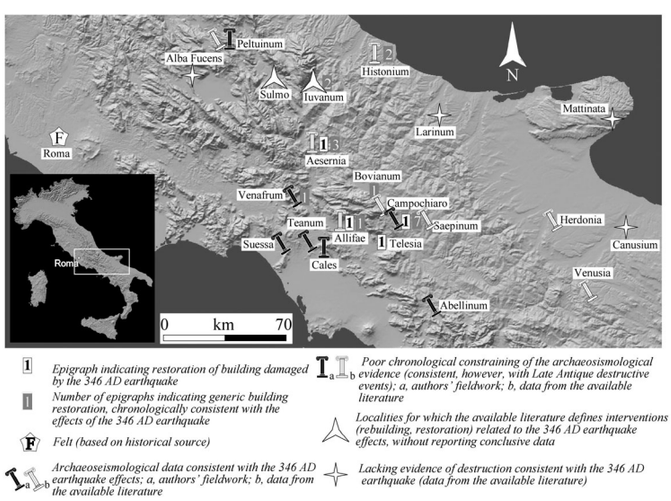

Fig. 3. Location map of the localities mentioned in the text and summary of the archaeoseismological data related to the 346 A.D. earthquake. Different symbols define the type of information available at each site, according to the explanation reported in the legend. The available information has been plotted on a 1:250 000 scale DEM based on topographic data by Istituto Geografico Militare (Florence, Italy).

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ranean area» by Guidoboni *et al.* (1994). The word «earthquake» results from an integration of the text (epigraph 4 in the Appendix).

Based on the information derived from Hyeronimus and on this epigraphic material, Guidoboni *et al.* (1994) defined an area affected by the 346 earthquake in Italy (fig. 2), comprising Rome (felt) and Isernia-Aesernia, Alife-Allifae, Telese-Telesia and Sepino-Saepinum (damaged).

The texts of other twelve epigraphs mentioning restorations or rebuilding of edifices or city walls was reported by Guidoboni (1989). These epigraphs testify to the significant building activity of the governor Fabius Maximus in the towns of Allifae-Alife, Saepinum-Sepino, Aesernia-Isernia, Histonium-Vasto and Iuvanum-Monterodomo (fig. 3 for the location). The texts of the epigraphs do not mention the earthquake as the cause of the building activity. However, since 1) the area of the Fabius Maximus' interventions was that affected by the 346 event and 2) the age of these interventions is immediately subsequent to the earthquake, a direct relationship between the building program of this governor and the earthquake effects has been hypothesised (*e.g.,* Camodeca, 1972).

3. Further epigraphic information and the problem of the Samnium governors

The texts of the other five epigraphs mentioning restorations or rebuilding at Saepinum-Sepino (three epigraphs), Bovianum-Boiano and Venafrum-Venafro have been reported in the Appendix (nos. 12, 14, 18, 19, 20). These epigraphs confirm the significant building activity at Saepinum in the years subsequent to the earthquake and permit us to include Bovianum and Saepinum among the localities which experienced interventions possibly conditioned by the earthquake effects.

As in the cases reported in the previous section, the above mentioned epigraphs also describe the activity of two Samnium governors, *i.e.* Fabius Maximus (for Bovianum and Saepinum) and Autonius Iustinianus (for Venafrum). Both the governors were active in the years immediately subsequent to the earthquake, but the precise age of the governorships is unknown. This aspect is by no means trivial since these ages may place further chronological constraints on the earthquake. Unfortunately, different hypotheses are available on this issue. The epigraph mentioning restorations to the city walls of Aesernia (CIL IX 2639) by Fabius Maximus can be related to the time spans 352-354 and 356-357 A.D. (Mommsen, 1883; Russi, 1971; Gaggiotti, 1978).

This means that Fabius Maximus was the governor of the Samnium province at least in a period following the mid 4th century A.D. According to Gaggiotti (1978), Autonius Iustinianus was the governor of the province between 346 and 351/6 A.D. In this way it is possible to fill the gap of the governors between the age of the earthquake (*i.e.* the presumed age of creation of the province) and Fabius Maximus's governorship. More recently, Gambardella (2001) hypothesised that Autonius Iustinianus's governorship was subsequent to 375 A.D. This researcher considers that the word «earthquakes» reported in the epigraph CIL IX 2638 (from Aesernia, no. 1 in the Appendix, related to restorations by Autonius Iustinianus) probably defines the cumulated effects of the 346 and 375 A.D. earthquakes. The latter event actually occurred shortly before 375 A.D. (*e.g.,* Guidoboni, 1989; Guidoboni *et al.*, 1994) and probably affected part of the area struck by the 346 earthquake.

The weakness of both hypotheses on the chronology of the governorships is due to the use of external and debatable data related to earthquakes whose age is not precisely defined (particularly the 346 event, with the implication of the uncertain date of formation of the Samnium province). Moreover, it is not possible to exclude that other earthquakes affected the investigated region between 346 and 375 A.D. It is evident, therefore, that the present chronological interpretations of the governors' succession are far from being conclusive in the perspective of better defining or confirming the age of the 346 A.D. event.

4. Archaeological evidence

The possible archaeological evidence of coseismic damage, restorations, rebuildings or abandonments related to a time span consistent with the occurrence of the 346 earthquake is

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Table I. Summary of the available archaeological data related to the 346 A.D. earthquake. The classification of the effect follows the representation of fig. 3: 1) archaeoseismological data consistent with the 346 A.D. earthquake effects (a, authors' fieldwork; b, data from the available literature); 2) poor chronological constraints on the archaeoseismological evidence (a, authors' fieldwork; b, data from the available literature); 3) localities for which the available literature defines interventions (rebuilding, restoration) related to the 346 A.D. earthquake effects, without reporting conclusive data; 4) lacking evidence of destruction consistent with the 346 A.D. earthquake.

Locality (name during the Antiquity)	Locality (present name)	Epigraphic source (mid 4th century A.D.)	Effect	Archaeological source	Effect	Chronological constraint	Classification of the effect
Peltuinum	Peltuinum	–	–	Sommella (1989); Authors' fieldwork during recent archaeological excavations.	Collapse of the vaults of the theatre; collapse of a reservoir in the Forum; damage and collapse of the walls of the temple temenos.	Coin of Constantius the 2nd (337-361 A.D.) in deposits sealed by the ruins of the temple.	
Venafrum	Venafro	CIL X 4858	General restorations of the town	Genito (1984), Genito (1998), Capini (1990), Capini (1991), Authors' fieldwork.	Collapse of the theatre (fig. 4); accumulation of recovered material in a locality nearby.	Re-use of the degraded structures since the 5th century A.D.; re-use of material of the collapsed structure for new buildings since that period.	
Teanum	Teano	–	–	Gasperetti (1999) Authors' fieldwork during recent archaeological excavations.	Widespread evidence of sudden collapse of the theatre; rotation of pillars; evidence of ejection of statues and architectural decorations (fig. 5a-d).	Radiocarbon date of a charcoal fragment (sample TEA-2 of table II) collected in the layer sealing the collapse (435-630 A.D.); pottery shards (4th cent. A.D.) found together with the material recovered during the Antiquity.	
Suessa	Sessa Aurunca	–	–	Cascella (2002) Authors' fieldwork during recent archaeological excavations.	Widespread evidence of sudden collapse of the theatre (vault of the southern basilica; crypt of the summa cavea; porticus post scenam; northern chalcidicum; scaena) (fig. 6a-e).	Pottery shards (4th-5th century A.D.) in the layer of abandonment sealed by the collapse; pottery shards (until the 7th century A.D.) in the layer sealing the collapse.	

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Table I (*continued*).

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Cales	Calvi Risorta	–	–	Authors' fieldwork during recent archaeological excavations	Widespread evidence of sudden collapse of the theatre (entire walls of the scaena, pillars, columns, architectural decorations) (fig. 7a-d)	Presence of a layer of reworked material («layer of abandonment») generally indicating an occurrence since Late Antique periods	I
Saepinum	Sepino	1. Buonocore (1992); 2. CIL IX 2447; 3. CIL IX 2448; 4. CIL IX 2449; 5. Gaggiotti (1991b); 6. Gaggiotti (1978); 7. Gaggiotti (1978); 8. CIL IX 6307.	1. Restoration of the market collapsed because of the earthquake. 2. Restoration of the thermae. 3. Building of the tribunal. 4. Restorations. 5. Building and decoration of the tribunal. 6. Restoration of the porticos of the thermae. 7. Building and decoration of the basilica. 8. Building.	Gaggiotti (1991a); De Benedittis *et al.* (1993); Lloyd *et al.* (2001); Cianfarani (1950); Cappelletti (1988); Authors' fieldwork during recent archaeological excavations.	Widespread restorations in the half of the 4th century; collapse of the northern tower along the city walls; sudden collapse of the SW sector of the city walls; collapse of the tower along the SW sector of the city walls; restoration of the SE side of the Forum (fig. 8a-d).	Burials ranging in age between the 5th and the 7th century A.D. excavated within the reworked material sealing the ruins of the northern tower; radiocarbon date of a burnt wood fragment (360-80 B.C.; sample SEP-3 of table II) in the layer underlying the collapsed city walls (lower chronological limit); radiocarbon date of a burnt wood fragment (20-220 A.D.; sample SEP-8 of table II) from reworked material sealing the ruins of the SW tower (probably defining a lower chronological limit for the collapse); coin of Constans (341-346 A.D.) in the pier of the new floor in a room of the SE side of the Forum.	I I
Abellinum	Atripalda	–	–	Colucci Pescatori (1986); Authors' fieldwork.	Collapse of walls and columns in the peristyle of a domus and abandonment of the building (fig. 9).	Volcanic materials related to the 472 A.D. Mt. Vesuvium eruption sealing the ruins; coins of Constans (337-350 A.D.) and Constantius the 2nd (337-361 A.D.) in the layer of abandonment preceding the eruption.	I

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Table I (*continued*).

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Sulmo	Sulmona	–	–	Tuteri (1996); Tuteri (1999).	Rebuilding and enlargement of a domus during the 4th century; significant restorations of a floor with a mosaic.	Pottery shards (mid-4th century A.D.) underlying the new floor.	
Histonium	Vasto	1. CIL IX 2842; 2. CIL IX 2843.	1. Restoration of the Capitolium. 2. Probable restoration.	Staffa (1998); Migliorati (1999).	Widespread restorations by using despoliated material and the technique of opus listatum; cracks affecting a reservoir.	Use of despoliated material (typical of Late Antiquity); use of the technique of the opus listatum (typical of Late Antiquity).	
Iuvanum	Montenerodomo	1. CIL IX 2956; 2. CIL IX 2957.	1. Restoration of the public walls. 2. Building of the secretarium.	Staffa (1997); Garofalo (2003).	Horizontal shifting of parts of a column.	–	
Aesernia	Isernia	1. CIL IX 2638; 2. CIL IX 2639; 3. CIL IX 2640; 4. CIL IX 2643.	1. Restoration of the market destroyed by the earthquake. 2. Restoration of the public walls. 3. Restoration. 4. Building.	Catalano *et al.* (2001).	Trabeation of a temple with an attitude subsequent to an event of collapse; sudden destruction of the northern border of the thermae.	Age of the damaged temple (3rd century B.C.); age of the thermae (generally imperial).	
–	Campochiaro	–	–	Cappelletti (1991); Galli *et al.* (2002).	Abandonment of the temple.	Coin of Constantine the 1st (related to 325-330 A.D.) and other materials defining a human frequentation not later than the half of the 4th century.	
Allifae	Alife	1. CIL IX 2338; 2. CIL IX 2337.	1. Reconstruction of the thermae destroyed by the earthquake. 2. Building of the city walls.	Gambardella (2001).	Collapse of the walls of some houses; collapse of the vault of a reservoir.	Pottery shards (3rd cent. A.D.) below the collapsed vault of the reservoir.	

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Table I (*continued*).

Locality (name during the Antiquity)	Locality (present name)	Epigraphic source (mid 4th century A.D.)	Effect	Archaeological source	Effect	Chronological constraint	Classification of the effect
Herdonia	Ordona	–	–	Mertens and Volpe (1999); Volpe *et al.* (1999).	Widespread evidence of sudden collapse of edifices (basilica; domus A); significant restorations (domus B; gymnasium; thermae); abandonment of edifices (macellum).	Archaeological material (pottery shards, coins); style of the restorations.	1b
Venusia	Venosa	–	–	Salvatore (1989).	Intense fracturing of walls in the amphitheatre; ruins of a domus; general decadence and abandonment of the town.	Coins of Constantius the 2nd and Constantius Gallus (350-355 A.D.) within the floor of the collapsed domus; coins of Constans and Valentinianus the 3rd (340-450 A.D.) in the reworked material sealing the ruins.	1b
Telesia	Telese	Camodeca (1972).	Reconstruction of the thermae destroyed by the earthquake.	–	–	–	–
Larinum	Larino	–	–	Di Niro (1991).	Restorations of the forum until the 4th century A.D., but not consistent with effects related to the 346 earthquake.	–	4
Matinum	Mattinata	–	–	Volpe *et al.* (1998).	Continuity of the settlement in the Villa of Agnuli between the 1st cent. B.C. and the 6th century A.D. (architectural modifications during the 3rd century A.D.).	–	4
Canusium	Canosa	–	–	Campione and Nuzzo (1999)	Urbanistic modifications related to the end of the 4th century A.D.; thermae modified during the 5th-6th century A.D.	–	4
Alba Fucens	Albe	–	–	Mertens (1969); Mertens (1991); Liberatore (2001); Campanelli (2001)	Widespread evidence of sudden destruction not preceding the end of the 4th century A.D.	–	4

1a 1b 2a 2b 3 4

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summarised in table I and fig. 3. The archaeological data from numerous sites of central-southern Italy have been derived from the available literature or from unpublished archaeological material, deposited in the local Archaeological Archives. This material has been systematically analysed and discussed with the archaeologists who directed the excavations or have in-depth knowledge of a certain archaeological site (*e.g.*, Sulmo-Sulmona and Larinum-Larino, fig. 3 for location). In some cases (Peltuinum, Teanum-Teano, Cales-Calvi Risorta, Suessa-Sessa Aurunca, Saepinum-Sepino), we worked in the field during (or short time after) the archaeological excavations. In other cases (Venafrum-Venafro, Abellinum-Atripalda), we had the opportunity to check the published archaeological data in the field, together with the archaeologists responsible for the excavations. This permitted us to collect data in the archaeoseismological perspective (a secondary issue in the work of an archaeologist), to discuss with archaeologists during data collection and to collect samples for radiocarbon dating (table II). This procedure is, in our opinion, the best to define the role of an earthquake in the history of an archaeological site. It cannot be applied, however, to all the sites of interest for the 346 earthquake. Many sites are, indeed, known from excavations of several decades ago. In these cases, only a critical approach to the available literature (sometimes supported by discussion with the archaeologists who made the excavations) permits us to make hypotheses on the possible effects of the investigated earthquake.

Fieldwork also permitted us to exclude the possibility that other natural causes of destruction had an impact on the investigated sites (*e.g.,* landslides or differential settlements; Karcz and Kafri, 1978; Stiros, 1996). Geomorphology of the sites was investigated through the analysis of aerial photographs. Data on the foundation soils were also collected in the field. The sites where we had the opportunity to do some fieldwork (fig. 3) are located in flat areas and founded in uncompressible sediments or in rocks. This defines geomorphic stability which has been considered a prerequisite to include the site with traces of destruction among those of archaeoseismological interest. As for the causes of destruction due to human actions (Karcz and Kafri, 1978; Stiros, 1996), we can exclude the occurrence of wars in this part of the Roman empire during the period of the investigated earthquake. We cannot exclude, however, that the lack of maintenance of the edifices (quite common during Late Antiquity) conditioned our archaeoseismological interpretation. The influence of the lack of maintenance can be twofold: 1) it can be the cause for collapses wrongly interpreted as coseismic and 2) it can cause a significant increase in vulnerability. Considering point 1, we gave importance to the evidence of sudden collapse of huge portions of edifices. Moreover, we excluded collapses affecting small parts of walls and the evidence of progressive collapses due to the decay of an edifice. Although this procedure does not rule out that the structural decay is

Table II. Radiocarbon dates of samples collected in the investigated area. The analyses were made by BETA Analytic, Miami. AMS, accelerator mass spectrometry technique.

Sample	Lab.code Beta -	Analysis	C13/C12 Ratio	Measured age B.P.	Conventional age B.P.	Calibrated age 1σ B.P.	Calibrated age 1σ B.P.	Sample description
SEP-3	163999	AMS	–25.3 ‰	2160 ± 40	2160 ± 40	350-160 B.C.	360-80 B.C.	charcoal
SEP-8	164000	AMS	–24.6 ‰	1900 ± 40	1910 ± 40	60-130 A.D.	20-220 A.D.	charcoal
TEA-2	137421	AMS	–26.0 ‰	1540 ± 40	1520 ± 40	530-600 A.D.	435-630 A.D.	charcoal

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the cause of a damage, at least we excluded effects that certainly can be considered the result of age or lack of maintenance. As for point 2, we cannot exclude the possibility of an overestimation of the earthquake size through the incorporation of collapsed structures affected by a high vulnerability. The implication of this issue will be discussed in the next section.

A short description of the available archaeological material for each investigated site is proposed in table I. The sites where we did some fieldwork are first reported (Peltuinum to Abellinum-Atripalda) from north towards south. The sites for which only bibliographical information is available (Sulmo-Sulmona to Venusia-Venosa) are then described, following the same geographical criteria. Figures 4-9 document some of the investigated sites.

Fig. 4. Venafro-Venafrum: decorative parts of the theatre collapsed within the *cavea*. The area was still in use when the collapse occurred, as indicated by the lack of a layer containing reworked material, related to an abandonment phase.

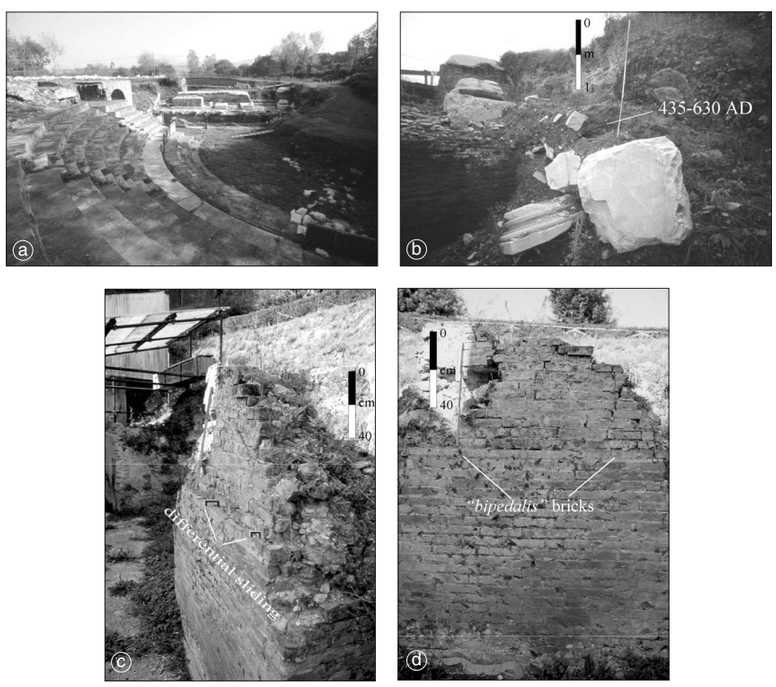

Fig. 5a-d. Teano-Teanum: a) panoramic view of the theatre; b) decorative parts of the scaena ejected towards the *cavea*; the ruins are sealed by a layer containing burnt wood fragments radiocarbon dated at 435-630 A.D. (2 σ cal. age); c, d) differential sliding occurred along a row of largest bricks (*bipedalis*) in the external wall of the theatre.

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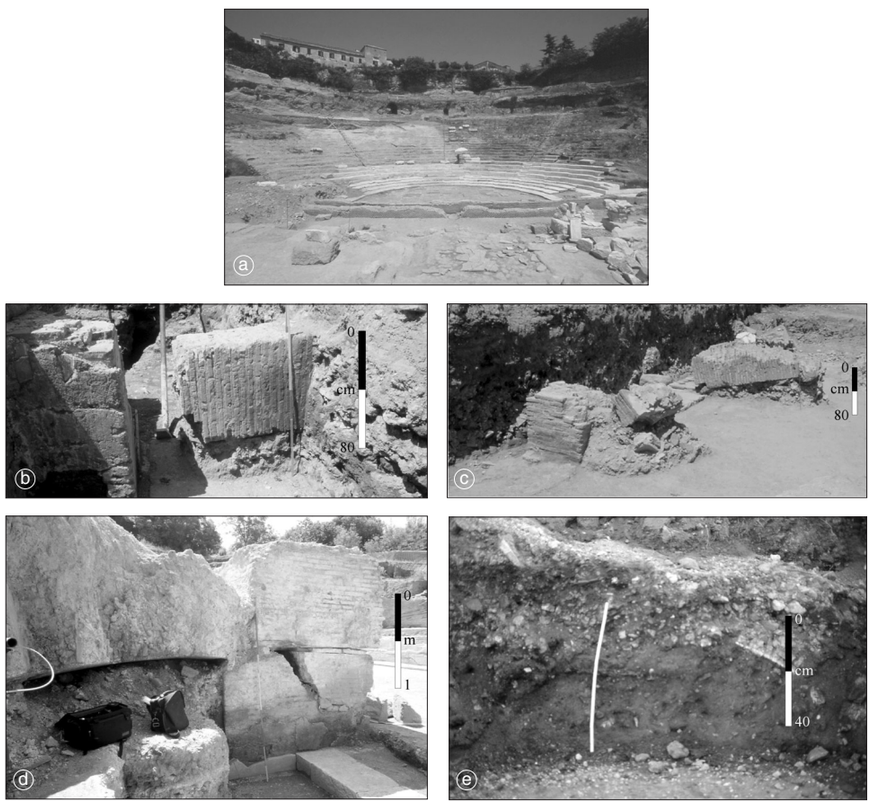

Fig. 6a-e. Sessa Aurunca-Suessa: a) panoramic view of the theatre; b,c) collapsed (toppled) pillars in the sector of the scaena; d) partial sliding of a huge pillar over the largest bricks (*bipedalis*) conditioned by the collapse of part of the vault in the *cavea*; e) thick layer of reworked material accumulated in the *cavea* and underlying the collapsed blocks; this layer indicates that the theatre was already abandoned at the time of the collapse.

Fig. 7a-d. Calvi Risorta-Cales: a) panoramic view of the theatre; b) collapse of the walls in the frontal part of the *scaena*; the collapse occurred partly over debris derived from the upper part of the structure, partly over reworked material continuously accumulated due to the lack of maintenance; c) collapsed columns; d) decorative parts in the sector of the *scaena*, included in the debris derived from the collapse of the theatre.

Fig. 8a-d. Saepinum: a) b) c) d) collapsed city walls. The archaeological excavations uncovered huge blocks which had collapsed through a mechanism of toppling (b) or ejected from the upper parts of the walls and presenting an imbricated pattern (c, d). The size of the blocks and the general absence of thick debris below them suggest that the collapse occurred suddenly, when the city walls were still maintained. Based on the radiocarbon date of burnt wood fragments below the ruins, the collapse occurred after 20-220 A.D. (2 sigma radiocarbon age).

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Fig. 9. Abellinum: collapse of columns in the peristyle of a domus within a bath still in use at the time of the destruction (lack of reworked materials defining a layer of abandonment).

5. Discussion

The archaeoseismological analysis of the 346 A.D. earthquake followed «areal» procedures already tested in other case studies (*e.g.,* the 374 A.D. earthquake in Sicily, investigated by Guidoboni *et al.*, 2000; the 365 A.D. earthquake in the Eastern Mediterranean Sea, investigated by Stiros, 2001). The approach aimed at defining the possible damage distribution of an ancient earthquake through the investigation of numerous archaeological sites of a region and by merging this information with that available from historical sources. The new data have increased the number of localities for which damage due to the 346 event can be hypothesised. Indeed, the damage in a vast portion of central-southern Italy can be inferred from fig. 3. The sites where damage related to one or more events in the mid 4th century seems more probable are (from north): Peltuinum, Aesernia-Isernia, Venafrum-Venafro, Cales-Calvi Risorta, Teanum-Teano, Suessa-Sessa Aurunca, Telesia-Telese, Allifae-Alife, Campochiaro, Saepinum-Sepino, Abellinum-Atripalda, Venusia-Venosa, Herdonia-Ordona (fig. 3). If this picture is real and, more importantly, if the presumed coseismic effects are related to the same event, we have an image of a very strong earthquake. In particular, the distribution of the presumed damage throughout much of southern Italy recalls the damage pattern of the 1456 earthquake sequence (fig. 1b). Therefore, if the archaeoseismological interpretation is correct, the 346 earthquake may be an «ancient analogue» of the 1456 sequence. This may justify 1) the use of the word «earthquakes» instead of «earthquake» in the epigraph of Autonius Iustinianus from Aesernia and 2) the fact that Rome was shaken for three nights, according to Hyeronimus.

Alternatively, if the damage has been strongly conditioned by the high vulnerability of ancient buildings (in many cases already abandoned when the collapse occurred) and therefore the available picture overestimates the earthquake size, the 346 earthquake may be compared to the 1805 event. The damage due to the latter (fig. 1d) is, indeed, located in the central portion of the area possibly struck

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by the 346 event. In contrast, the 1349 sequence (fig. 1a) also struck areas located North of that represented in fig. 3, while the highest intensity datapoints of the 1688 earthquake (fig. 1a-d) are located South of the area for which more data on the presumed 346 effects are available.

The different hypotheses are, however, strongly conditioned by the problems which usually affect archaeoseismological data (reliability of the interpretation of the presumed archaeoseismological evidence; length of the time span within which the sudden event can be located) and by historical factors.

The interpretation of sudden collapses, abandonments, re-buildings, restorations in a seismological perspective is generally not univocal, even if the archaeological data are accompanied by presumed striking coseismic evidence (*e.g.,* the rotation of pillars at Teanum) or epigraphic material. The effectiveness of the «rule of consistency», *i.e.* the certification of the occurrence of the above mentioned events at different sites of an area within a certain time span, may be limited in practical terms. Sudden collapses or restorations may be due to non coseismic causes and/or may have occurred within a time span (archaeologically defined) of several decades, during which a number of destructive events (not necessarily of seismic origin) may have affected the investigated area.

It is clear, therefore, that the chronology of an archaeological event is another fundamental aspect to hypothesise a damage pattern such as that proposed above for the 346 event. The chronological comparability of wall collapses, abandonments, re-buildings or restorations across the different archaeological sites strongly depends on the amplitude of the time span within which an archaeologically detected event can be located. In this light, it is evident that the chronological constraints for some archaeological sites can be considered insufficient to relate presumed coseismic damage to the 346 earthquake. For example, in the cases of Aesernia-Isernia and Histonium-Vasto, the chronological constraints are faint. The destructive event/s can be attributed to Late Antiquity, but more detailed chronological data are lacking. In other cases (*e.g.,* Peltuinum, Teanum, Suessa, Venafrum) the destructive event can be located within a time span in the order of a century or slightly more. Only in some cases (*e.g.,* Campochiaro, Saepinum, Venusia, Abellinum) do the chronological constraints point to the occurrence of a destructive event in about mid of the 4th century A.D. For this reason, the available data cannot be used to define a picture of the 346 earthquake as expected for a modern earthquake. Therefore, more than a «deterministic» definition of a damage pattern (similar to that of a more recent historical earthquake), fig. 3 defines a picture of localities for which the available data are «consistent» (*i.e.* may be related) with the effects of the 346 A.D. earthquake. This means that fig. 3 defines a sort of maximum possible area of damaging effects related to this event. Negative evidence of the earthquake towards E (Larinum-Larino), SE (Mattinata, Canusium) and towards N (felt in Rome; absence of evidence for Alba Fucens) limits the territory possibly struck by the seismic event.

However, the previously discussed unsolved archaeoseismological issues suggest another possibility, *i.e.* that the 346 earthquake damage affected a more limited portion of the investigated area. If fig. 3 represents an extreme, probably «enlarged» view of the earthquake, the other extreme, «reduced» view of this event may be represented by only five points (already reported in Guidoboni *et al.*, 1994): Allifae-Alife, Telesia-Telese, Aesernia-Isernia, Saepinum-Sepino (epigraphs mentioning the earthquake occurrence), Rome (felt, on the basis of Hyeronimus) and the general indication of the damage in the Campania province, comprising the Samnium area (from Hyeronimus) (fig. 2).

Therefore, in our opinion, the 346 earthquake may be represented by two «extreme» views (defining limits of an interval): 1) the conclusive data which define the localities struck by the earthquake («reduced» view; fig. 2) and 2) these data plus all the available information which defines possible evidence of damage consistent with the 346 earthquake («enlarged» view; fig. 3). This approach simply considers that the earthquake effects are neither lower than those represented in fig. 2 nor larger than those reported in fig. 3.

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6. Conclusions

According to the sparse historical sources, the 346 A.D. earthquake damaged at least four ancient towns of southern Italy and was felt in Rome.

Considering the scarcity of the historical sources on the 346 A.D. earthquake (central-southern Italy), we tried to improve our knowledge on this event through archaeoseismological analysis. Investigations have been performed by means of fieldwork during archaeological excavations at key-sites and the critical review of the published archaeological material.

The archaeological data yield a picture of possible coseismic effects in a large part of southern Italy. However, factors such as: 1) the problematic attribution of the seismic cause to all the archaeological cases of destruction; 2) the occurrence of more earthquakes in a short time span (346 A.D., 375 A.D.) in the same area, whose effects are difficult to distinguish also by means of a detailed and rich archaeological stratigraphy and 3) the increased vulnerability of many structures during Late Antiquity, may be responsible for a sort of amplification of the earthquake size.

Taking these problems into account, the two extreme points of the knowledge should be represented (*e.g.,* two different pictures of the earthquake should be available): 1) the data univocally indicating the earthquake occurrence and 2) data of point 1 plus the critically reviewed archaeological data consistent with the earthquake occurrence.

This procedure defines the extreme views of the earthquake damage, thus giving a representation different from that typical of more modern historical earthquakes. Since some of the issues indicated in the previous points are common to most ancient earthquakes, we believe that reliable pictures of these events may be obtained through a sistematic use of the defined procedure.

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Appendix

Epigraphs mentioning the building activity of Fabius Maximus and Autonius Iustinianus

As reported in the section dedicated to the historical aspects of the 346 earthquake, the text of three epigraphs (nos. 1-3, in this appendix) mentioning the earthquake as the cause of necessary restorations (in Aesernia, Telesia and Allifae see fig. 2) are reported in Guidoboni (1989). Another epigraph (no. 4, in this appendix) mentioning the earthquake (as a result of integration of the text) has been published by Buonocore (1992) and mentioned by Guidoboni *et al.* (1994). Twelve epigraphs (nos. 5 to 11, 13, 15 to 17 and

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21) denouncing rebuilding or restorations by Fabius Maximus (governor of the Samnium province) possibly related to the earthquake have already been reported in Guidoboni (1989). Note that the information reported on epigraphs nos. 6 and 10 is very scarce. Actually it is not possible to establish if the texts are related to the restoration activity promoted by Fabius Maximus. Here we report the text of other five epigraphs (nos. 12, 14, 18, 19 and 20) mentioning the building activity by Fabius Maximus and Autonius Iustinianus, possibly related to the effects of the earthquake.

1. *Isernia - Aesernia*
CIL IX 2638
Macellum terrae motibus lapsum | A[u]tonio Iustiniano rectore | provinciae disponen(te) | Castricius vir primarius | sumptu proprio | fieri curavit cum Silverio filio | acceptis columnis et tegulis | a re publica.
transl.: « At the solicitation of Autonius Iustinianus, governor of the province, Castricius, important man, arranged with his son Silverius the restoration of the market which was destroyed by the earthquake, at his own expenses, with columns and tiles supplied by the State».

2. *Alife - Allifae*
CIL IX 2338
Fabius Maximus v(ir) c(larissimus) rect(or) prov(inciae) | thermas Herculis vi terrae mo | tus eversas restituit a fundamentis.
transl.: «Fabius Maximus, illustrious man, governor of the province, reconstructed from the foundations the thermae of Hercules, destroyed by the violence of the earthquake».

3. *Telese - Telesia*
(Camodeca, 1972)
Fab[ius Maximus v c] | rect(or) [prov thermas] | Sabi[nianas vi terrae mo] | tus e[versas a fundamen] | t[is restituit].
transl.: «Fabius Maximus, illustrious man, governor of the province, reconstructed from the foundations the Sabinian thermae, destroyed by the violence of the earthquake».

4. *Sepino - Saepinum*
(Buonocore, 1992)
Auton[ius Iustinianus] | rector p[rovinciae] | macellu[m terrae motum] | [la]p[sum restituit]|
transl.: «Autonius Iustinianus, governor of the province, restored the market which collapsed because of the earthquake».

5. *Vasto - Histonium*
CIL IX 2842
[C]apitolium | [F]abius Maxim[us] | v(ir) c(larissimus) | [i]nstaurav[it].
transl.: «Fabius Maximus, illustrious man, restored the Capitolium».

6. *Vasto - Histonium*
CIL IX 2843
[—-]*MUS*[—-] | [—-]*ICUMI*[—-] | [Fab]*io Maxi*[mo].

7. *Montenerodomo - Iuvanum*
CIL IX 2956
[Fabio] Maximo | v(iro) c(larissimo) | [rect]ori provinciae | [resta]uratori | [moe]nium publico | rum | [ordo i]uvanensium | patrono.
transl.: «The order (of the decurions?) of Iuvanum, to Fabius Maximus, illustrious man, governor of the province, patron, restorer of the public walls».

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8. *Montenerodomo - Iuvanum*
CIL IX 2957
Fabius Max[i]mus v(ir) c(larissimus) | rector provinciae | secretariu[m] fecit | curant[e] ordine.
transl.: «Fabius Maximus, illustrious man, governor of the province, built the secretarium under the supervision of the order (of the decurions?)».

9. *Isernia - Aesernia*
CIL IX 2639
Fabio Maximo | v(iro) c(larissimo) | instauratori | moenium | publicorum | ordo et populus | curante Aurelio | Pauliniano cura | [t]ore et patrono | d(e)d(icatum) | VIII K(alendas) [—-] | D(omino) N(ostro) Co[nstan] | tio Aug(usto) V[—-].
transl.: «The order (of the decurions?) and the people (of Aesernia), to Fabius Maximus, illustrious man, restorer of the public walls, under the supervision of the patron Aurelius Paulinianus, dedicated eight days before the Kalendas... during the empire of Augustus Constantius».

10. *Isernia - Aesernia*
CIL IX 2640
[—-]*M*[—-] | [—-] *M*+ + + + [—-]*AM* | [Fabi]*us Maximus* | *v*(ir) *c*(larissimus) | [c]*ur*[—-].
transl.: «Fabius Maximus, illustrious man, restored(?)...».

11. *Isernia - Aesernia*
CIL IX 2643
[Fabius Max]imus v(ir) c(larissimus) | [—-]VM fecit | [—-]a pecuni(a).
transl.: «Fabius Maximus, illustrious man, built... with money».

12. *Venafro - Venafrum*
(CIL X 4858)
Statuam Autonio | Iustiniano praesidi pro | vinciae Samnitium re | luctanti congregata | omni multitudine civita | tis fusis praecibus ut suscipe | ret Venafranae urbis popu | lus conlocavit ob merita qui | bus una cum splendidissimo or | dine statum iam conlap | sum pro beatitudine saecu | li reparavit
transl.: «Having all the people of the city gathered so that they supported (it) with many prayers, the crowd placed a statue to Autonius Iustinianus, governor of the province of the Samnites, who was reluctant, for his merits whereby, for the joy of the century, he redressed with brilliant works the situation (of the city), by then fallen into ruin».

13. *Alife - Allifae*
CIL IX 2337
Fabio Ma | ximo v(iro) c(larissimo) | conditori mo | enium publico | rum vindici | omnium pecca | torum ordo et | populus Allifa | norum patrono.
transl.: «To the patron Fabius Maximus, illustrious man, founder of the city walls and avenger of all the evils, the order (of the decurions?) and the people of Allifae».

14. *Boiano - Bovianum*
(De Benedittis, 1988)
[F]abius Ma[ximus v c] | [a fundame]ntis secr[etarium fecit] | [curante Arrunti]o Attico [patrono Bovianensium]
transl.: «Fabius Maximus had the secretarium built from its foundations, under the supervision of the patron Arruntius Atticus».

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15. *Sepino - Saepinum*
CIL IX 2447
Fabius Maximus v(ir) c(larissimus) | re[c]tor provinciae | thermas Silvani vetustat(e) | conlabsas restituit | curante Neratio Consta[ntio] | patrono sumtu (sic) propio.
transl.: «Fabius Maximus, illustrious man, governor of the province, restored the thermae of Sylvanus collapsed because of its ancient age, at his own expenses, under the supervision of the patron Neratius Constantius».

16. *Sepino - Saepinum*
CIL IX 2448
[Fa]bius Maximus v(ir) c(clarissimus) | [a f]undamentis tri | [bu]nal columnatum fecit | [cu]rante Arruntio Attico patrono | [Sae]pinatium et Bovianensium.
transl.: «Fabius Maximus, illustrious man, had the tribunal built from its foundations with columns under the supervision of Arruntius Atticus, patron of the cities of Saepinum and Bovianum».

17. *Sepino - Saepinum*
CIL IX 2449
Fabio M[aximo] | v(iro) c(larissimo) | instau[ratori].
transl.: «To Fabius Maximus, illustrious man, restorer».

18. *Sepino - Saepinum*
(Gaggiotti, 1991b)
Fl(avius) Uranius v(ir) p(erfectissimus) rect(or) pr[ovinciae] | tribunal quod minus [ex] | ornatum repperit sple[ndore | ma]rmorum decoravit | curante Naeratio Constan[tio] | patrono Saepinatium civitatis |
[Fabi]us Maximus v(ir) c(larissimus) a fundamentis | [tribuna]l columnatum fecit | [curante Ar]runtio Attico patrono | [Saepina]tium et Bovianensium
transl.: «Flavius Uranius, perfect man, governor of the province, noted that the tribunal was not very much adorned, had (it) decorated with the splendour of marbles under the supervision of Naeratius Constantius, patron of the city of Saepinum.
Fabius Maximus, illustrious man, had the tribunal built from its foundations with columns under the supervision of Arruntius Atticus, patron of the cities of Saepinum and Bovianum».

19. *Sepino - Saepinum*
(Gaggiotti, 1978)
Fabius Maximus v(ir) c(larissimus) | porticus thermarum vetus | tate conlabsas restituit | curante Neratio Constantio | patrono Saepinatis urbis S(ua) p(ecunia) f(ecit)
transl.: «Fabius Maximus, illustrious man, restored the porticos of the baths collapsed because of ancientness under the supervision of Naeratius Constantius, patron of the city of Saepinum, accomplished at his own expenses».

20. *Sepino - Saepinum*
(Gaggiotti, 1978)
[Fabius Maximus v c] recto[r] | [provinciae basili]cam ma | [rmoribus exorn]atam fabricavit | [huius munici]pi ornatui | [curante Naeratio C]onstans | [tio patrono Saep c]ivi | [tatis]
transl.: «Fabius Maximus, illustrious man, governor of the province, for the embellishment of this municipium, built the basilica adorned with marbles under the supervision of Naeratius Constantius, patron of the city of Saepinum».

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21. Sepino - Saepinum
CIL IX 6307
Fabius Maximus | v(ir) c(larissimus) | curavit.
transl.: «Fabius Maximus, illustrious man, made».

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