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Paleoseismology related to deformed archaeological remains in the Fucino Plain

Implications for subrecent seismicity in Central Italy

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Abstract
During paleoseismological investigations on the seismogenic structure responsible for the 1915 earthquake in the Fucino Plain (Central Italy), some trenches were excavated at the intersection between Roman-age channels and a fault characterized by Holocene activity. Channel displacement observed within the trenches has been related to an event which occurred approximately between the 6th and 9th century A.D. Written records describing damage caused in Rome indicate that two strong events occurred during this period in Central Italy, although their epicentral areas are undefined. The first event occurred immediately before 508 A.D. while the second happened in 801 A.D. Two other earthquakes during this period (618 A.D. and 847 A.D.) are reported in catalogues, but without corresponding information regarding damage in Rome. Available information is not conclusive about the age of the earthquake responsible for the displacement of the channels although geological, historical and archaeological data indicate it is most likely related to the 508 A.D. event. Should the hypothesis regarding the age of the earthquake be correct, a subrecent, incompletely-documented earthquake may be related to a specific seismogenetic area. Taking into account that the paleoseismological analysis has highlighted a close similarity between the surface faulting pattern of this event and the one that occurred in 1915, the former may be a «twin» of the latter.

Key words *paleoseismology – archaeoseismology – historical seismology – Central Italy*

1. Introduction

As historical records related to ancient strong earthquakes are usually incomplete, more information is required to better understand these past events in order to use them for seismic hazard assessment; the incorporation of various different disciplines may provide the necessary data. One possible approach involves the use of paleoseismological techniques to detect the geological effects of past earthquakes and to obtain the best chronological constraints for the observed coseismic deformations. The subsequent step requires the obtained paleoseismological data to be compared (if possible) with the historical seismic record of the study area in an effort to attribute a precise date to the coseismic geological effects.

The problems related to this kind of approach are magnified with regards to subrecent seismicity (*sensu* Karcz *et al.*, 1977), that is events that occurred during an ancient period for which largely incomplete historical infor-

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mation is available. In these cases the correlation between paleoseismological and historical data is more difficult due to the usual lack of knowledge regarding the location of the earthquake epicenter (*e.g.*, the Italian historical record for the second half of the first millennium A.D.; Guidoboni *et al.*, 1994; Boschi *et al.*, 1995). The comparison of paleoseismological and historical data on subrecent seismicity therefore requires the use of other kinds of constraints, such as archaeological indications of past earthquakes (*e.g.*, Stiros, 1988a; Armijo *et al.*, 1991; Mouyaris *et al.*, 1992; Pirazzoli *et al.*, 1992; Altunel and Hancock, 1993; D'Addezio *et al.*, 1995).

This paper presents the first case of coseismic displacements of archaeological remains in Central Italy (Fucino Plain) and its relationship with some strong subrecent earthquakes; historical knowledge of these events, which occurred during the second half of the first millennium A.D., is largely incomplete and the epicentral areas are unknown. This work attempts to define the best chronological constraints for the observed displacements, in order to relate the coseismic effects with the historical records of Central Italy. The approach used is prevalently geological (using paleoseismological techniques to investigate the coseismic deformations), but also contains historical data (from the available seismic catalogues) and archaeological indications of past earthquakes.

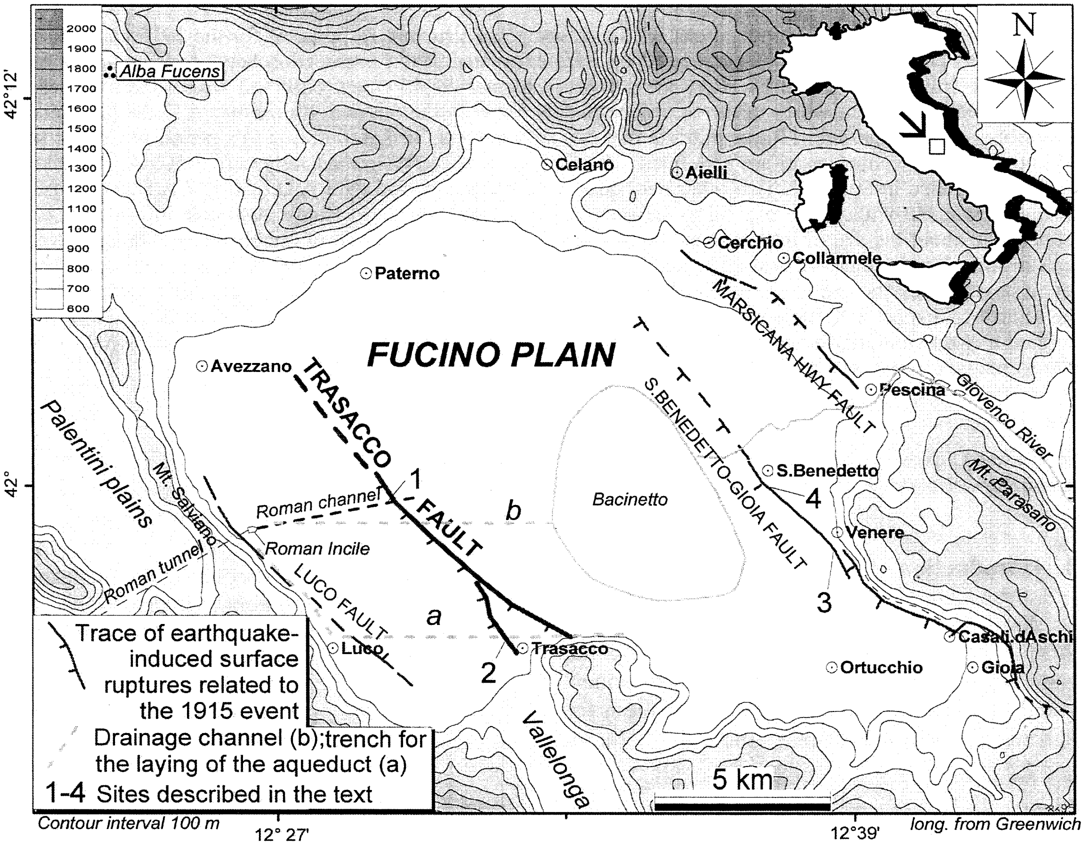

Fig. 1. Location map of the Fucino Plain.

2. Geological and seismological setting of the studied area

The Fucino Plain is one of the largest intramontane basins of Central Italy; it is surrounded by high carbonate reliefs (more than 2000 m in elevation) and locally contains > 1000 m thick lacustrine deposits. Tectonic activity during the Plio-Quaternary strongly influenced the formation and geological evolution of this basin. In fact, through the definition of the neotectonic history of the area, the basin has been interpreted as being the result of at least three distinct superimposed tectonic events (Galadini and Messina, 1994). During the most recent events, NW-SE normal faults played a major role in the evolution of the basin. In particular, the faults along the eastern border are responsible for the formation of a NW-SE half-graben whose evolution started during the Upper Pliocene or Lower Pleistocene. Among the minor NW-SE faults of the area, the Trasacco Fault (fig.1), originally identified by Giraudi (1986), is particularly important for the aim of this study.

The Fucino Plain was a lake until the 19th century, when it was drained for agricultural purposes. The first attempt to claim this land, however, was made during the 1st-2nd century A.D., when the Romans used an impressive hydraulic system, whose remains are still visible today, to partially drain the lake (fig. 1).

On January 13, 1915 this area was affected by a strong earthquake (M_s = 7.04, according to Margottini *et al.*, 1993; more than 30000 casualties). A description of the surface faulting due to this event is reported in Oddone (1915), while more recent data are reported in Serva *et al.* (1986) and Galadini *et al.* (1995). Geological data indicate normal movement during the 1915 event, along faults, reported in fig. 1, that were responsible for some several-decimetres-high scarps (Oddone, 1915).

Information available for the earthquake-affected area prior to 1915 consisted of a short historical seismic record characterized by only low-intensity events (Mercalli, 1883; Baratta, 1901). In retrospect it is surprising to consider that this earthquake was almost «predicted» by Omori (1909) through the simple definition of a gap in the seismicity related to strong Apennine earthquakes.

Recent paleoseismological research in the Fucino area (Giraudi, 1988; Galadini *et al.*, 1995; Michetti *et al.*, 1996) has recognized evidence for surface faulting events prior to 1915. In particular, Giraudi (1988) reported some geomorphological indications of paleoseismicity in the Fucino area, identifying four events during the last 20000 years (besides the 1915 event). This result was subsequently confirmed by Galadini *et al.* (1995) on the basis of more detailed paleoseismological research.

Michetti *et al.* (1996) recognized and dated two coseismic displacement events prior to 1915; according to these authors the observed deformations may be related to the 801 A.D. (High Middle Age event) and 1349 A.D. earthquakes (Low Middle Age event). Other paleoseismological data presented by Galadini *et al.* (1995), however, highlight the complexity of unequivocally defining a date for the High Middle Age event, and as such these authors did not propose a specific age for the event recognised as having likely occurred during the second half of the first millennium A.D.

3. The Roman drainage channels and the coseismic displacements

3.1. *Historical data*

As already mentioned, Lake Fucino was drained for the first time during the Roman age (the main historical sources include Plinius, I century; Svetonius, I-II century; Tacitus, I-II century and Cassius Dio, II-III century). The engineering works were originally started under emperor Claudius (emp. 41-54 A.D.), interrupted for a few decades, and then resumed under emperors Traianus (emp. 98-117) and Hadrianus (emp. 117-138). Under Antoninus Pius (emp. 138-161) the works were promoted to use the reclaimed land for agricultural purposes. Lake drainage was accomplished by the construction of a 5640 m long tunnel, in part under Mt. Salviano, and a main drainage channel more than 4 km long within the plain (fig. 1).

The operation of the Roman hydraulic structures probably ceased during the decadent period of the Roman Empire (end of 4th-5th century) and consequently the basin began to refill. The first known historical reference to the lake at its natural level is given for the second half of the 8th century (Leo Marsicanus sive Ostiensis, 11th-12th century), although Di Pietro (1869) describes the destruction of a settlement due to the flooding of the lake in the beginning of the 7th century (605 A.D.). A subsequent attempt to reclaim Fucino occurred under Frederick II, as stated in a document dated April 20, 1240 (Carcani, 1786). Other documents indicate that the works were executed, but probably without success; in fact on August 3, 1277 Charles I of Anjou issued a document which «permitted fishing» in the Lake Fucino (Filangieri 1950-1975). The continuous flooding of the lake also induced Alfonso I of Aragon (15th century) to try and repair the Roman drainage works (De Florentiis, 1977). His efforts were also unsuccessful and this was the last important attempt to drain the lake until the 19th century. The works for the final drainage, begun in 1862 and completed in 1875 (Brisse and De Rotrou, 1883), involved restoration of the ancient Roman tunnel and construction of a series of channels connecting it with the inner part of the basin. This drainage system consists of minor N-S and E-W channels and three main E-W channels.

3.2. *The geometry of the main Roman channel*

The trace of the main Roman channel, visible today on aerial photographs, is more than 4 km long and trends N78E (fig. 1). The cross-section of the structure was described in detail when it was intersected during the excavation of the most recent main drainage channel. At a distance of about 1000 m from the connection with the tunnel it was 7.5 m deep, 19.5 m wide at the top and 4.5 m wide at the base (Brisse and De Rotrou, 1883).

In the present study, the longitudinal profile of the channel has been reconstructed by means of hand bore-holes (fig. 2). Moreover, approximately 40 hand bore-holes were made in an effort to define the geometrical features of the channel in the area close to the fault (fig. 3). Recognizing the Roman channel base is extremely easy because of the sharp contrast between the fill sediments (very dark, due to the abundance of organic matter) and the sediments in which the channel was excavated (prevalently light-grey or yellowish lacustrine silts). As shown in fig. 2 the channel base dips towards the tunnel with a gradient of 0.05% between the 1000 m point (*i.e.*, distance to the tunnel opening) and the Trasacco Fault. Where the channel crosses the fault it clearly shows a displacement of 30-35 cm (east side up) and a backtilting towards the center of the lake.

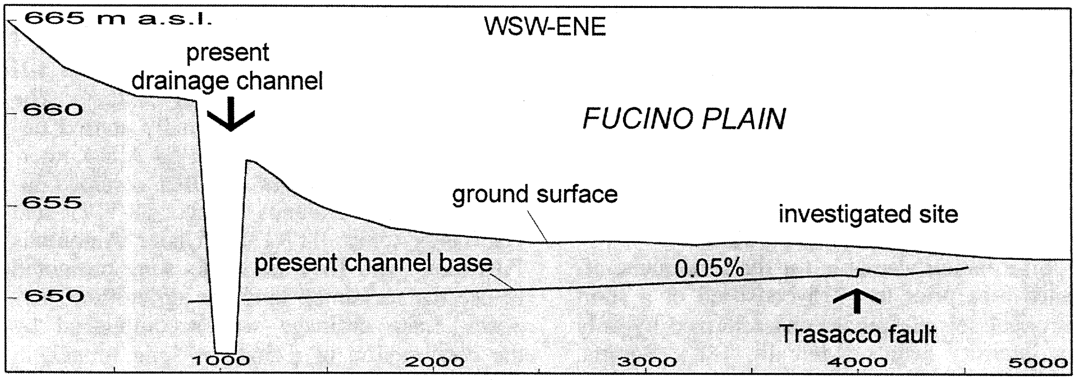

Fig. 2. Topographic profile of the studied area showing the base of the main Roman drainage channel. Note the displacement at the intersection between it and the Trasacco Fault.

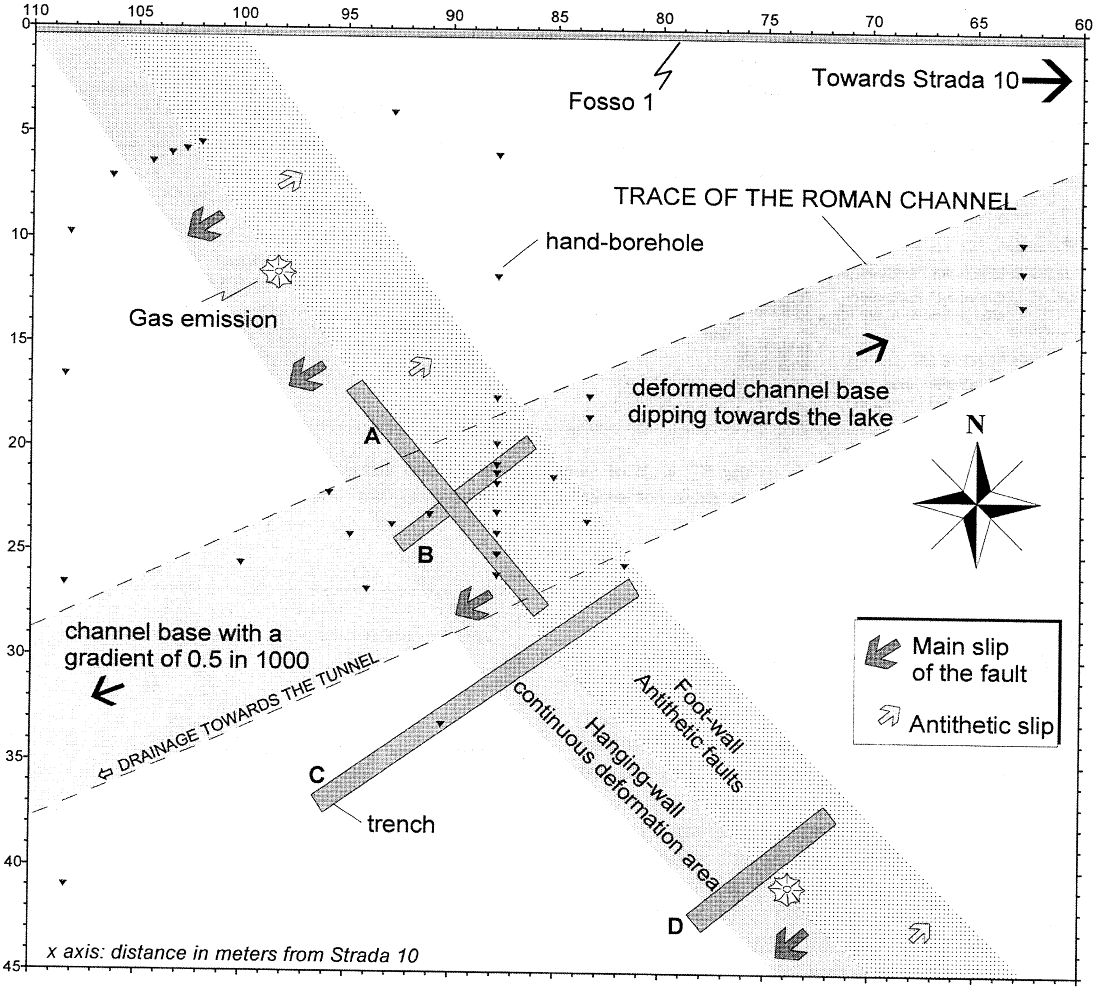

Fig. 3. Plan view of site 1 (fig. 1). Locations of trenches (A, B, C, D), hand boreholes (triangles), the NE-SW trending main Roman channel and the deformed area are shown.

3.3. *The trenches at site 1*

Four trenches were excavated where the channel intercepts the fault at site 1 (fig. 3): one perpendicular to the channel (A in fig. 3) and three parallel (one within the channel, B in fig. 3).

Trenches C and D in fig. 3 are characterized by the same stratigraphic and structural setting, and thus only the longer and deeper trench C is described here.

A clayey-silty lacustrine succession was exposed in trench C (fig. 4). The oldest sediments are blue-greyish clayey silts that have a yellowish colour at the top of the unit. Close to the top of this unit a tephra level is present, which Narcisi (personal communication) relates to the event responsible for the Biancavilla-Montalto ignimbrite (Mt. Etna, Southern Italy). An age of 14 180 ± 260 years B.P. is assumed for this tephra based on the radiocarbon dating of the ignimbrite (Narcisi, 1993).

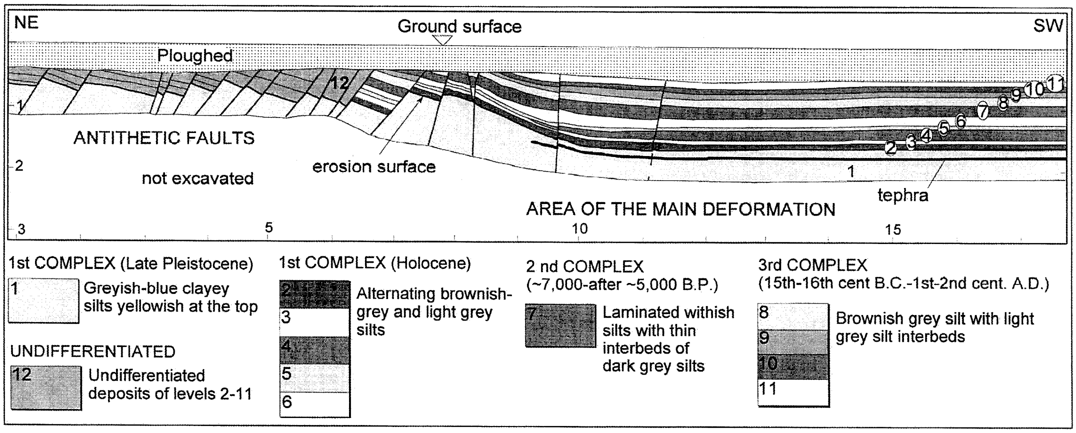

Fig. 4. Section corresponding to the SE wall of trench C, excavated across the Trasacco Fault at site 1 (see fig. 1 and 3). The distinction of the different sedimentary complexes is related to fig. 5.

In fig. 4 the younger deposits are greyish Holocene silts and clays.

Because of the lack of organic rich layers in the succession we have established the age of the Holocene deposits based on stratigraphic correlations with well-dated nearby successions. In fact, the long walls of the present main drainage channel (b in fig. 1) and of the trench recently excavated for the laying of an aqueduct permitted a complete stratigraphic framework to be defined for the western and inner sectors of the basin (fig. 5). Stratigraphic correlations and the available chronological framework indicate that the lacustrine sediments of the last 2000 years are lacking in trench C; it is most likely that they are contained within the ploughed soil.

The exposure in trench C is characterised by 10 m-wide zones of deformation formed by two distinct styles (fig. 4). In the SW sector deformation occurs by warping of the lacustrine deposits and subsidence to the SW, whereas the NE part shows a second order brittle deformation. The warping episodes caused no evident surficial breakage (as a main fault cutting the lacustrine succession is not present here) whereas the brittle deformation is represented by several NE-dipping, small-throw faults which caused the observed «domino»-style deformation. Some of the layers thicken

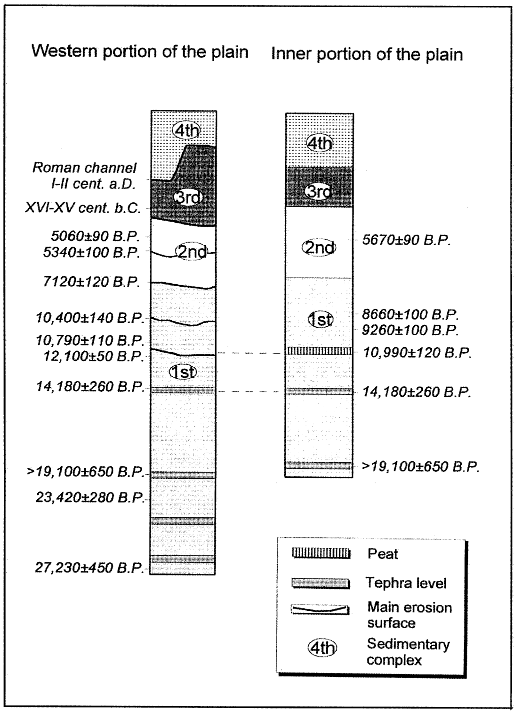

Fig. 5. Stratigraphic columns and definition of the different sedimentary complexes related to the western and inner portion of the Fucino Plain (from Galadini *et al.*, 1996).

on the downthrown side, due to movements of the structure during or immediately before the sedimentation of these levels. Due to the lack of sedimentary layers from the past 2000 years, fig. 4 does not show the deformations caused by the most recent displacement events, although the increasing thickness of the ploughed soil through the warped zone is a possible effect of deformations more recent than 2000 years.

A deformation obviously more recent than 2000 years is recorded in the section within the Roman channel (fig. 6a,b). As in the case of fig. 4, the entire deformation is the result of sediment warping (main deformation that caused a lowering of the SW side) and faulting. Each fault is characterized by a small, «domino»-style offset that results in a total displacement of zero, whereas the total vertical displacement due to warping is 30-35 cm.

The lower part of the sedimentary succession (A and B) is not related to a lacustrine depositional environment, but rather most likely represents deposition within the channel during and just after the drainage system ceased to function. Level C represents the first lacustrine episode at this site after the Roman drainage of the lake. Radiocarbon dating of level B sedi-

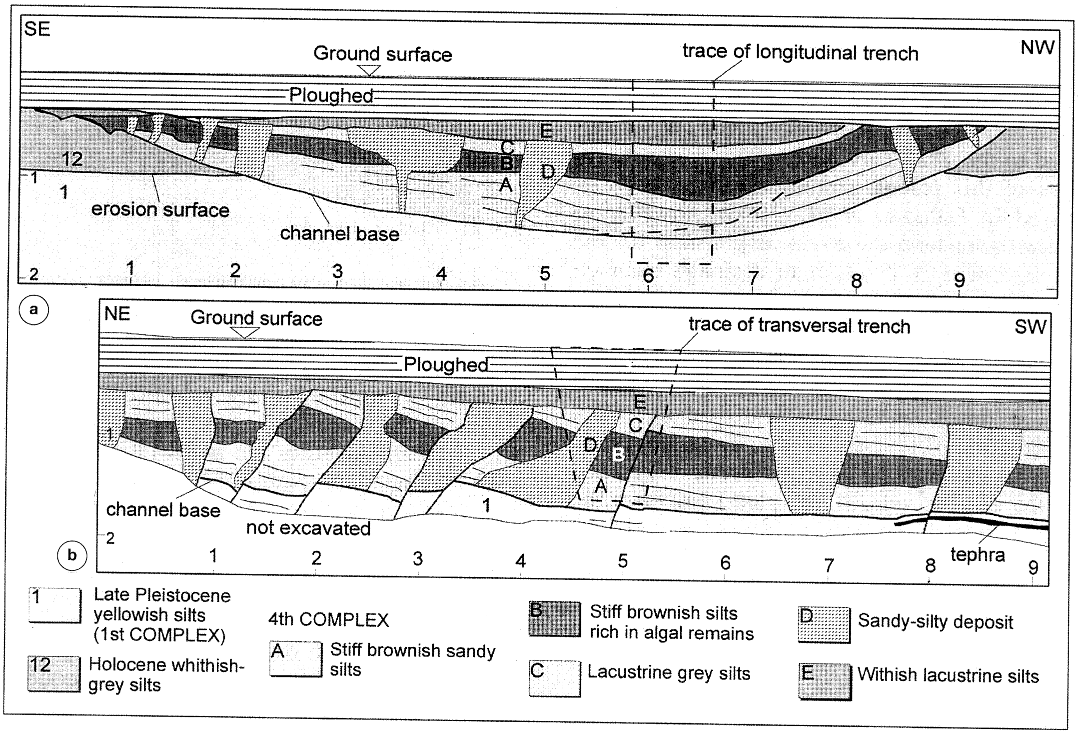

Fig. 6a,b. Sections corresponding to the SW wall of the transversal trench (a) and the SE wall of the longitudinal trench (b) excavated inside the main Roman channel where it intersects the Trasacco Fault (site 1 in fig. 1; trenches A and B in fig. 3). Units 1 and 12 are the same as those in fig. 4. Units A, B and C are the displaced channel fill. Sediments D consist of unstructured yellowish sandy silts that likely resulted from strong weathering due to the roots of dry-land or water plants. These deposits formed in E-W trending fractures (note that fracture widths appear greater than they actually are, as the trench is not perpendicular to the strike of these structures). The distinction of the different sedimentary complexes is related to fig. 5.

ments gave ages of 3490 ± 70 and 3390 ± 70 years B.P.; obviously these values are not representative of the true age of sediments filling a Roman channel. These out-of-sequence ages may be due to effects similar to those described by Branca *et al.* (1989) for other lacustrine sediments in Central Italy (*i.e.*, isotope fractionation).

On the basis of paleoseismological analysis, only one displacement episode is clearly visible which could have caused the described deformation. This episode occurred after the first lacustrine sediments were deposited following the end of the Roman reclamation (level C) and before the sedimentation of level E.

3.4. *Data from other sites*

In 1994-1995, 11 other trench and quarry walls were studied which cross the Trasacco Fault and other faults whose movement was related to the 1915 earthquake. The complete results of this paleoseismological study are discussed in Galadini *et al.* (1996), however to better understand the event responsible for the displacement of the Roman drainage channel, data from two of the studied sites (2 and 3 in fig. 1), as well as data from a site (4 in fig. 1) studied by Michetti *et al.* (1996) are presented below.

The trench at site 2 (located about 5 km south of site 1) crosses the Trasacco Fault, whereas the trenches at sites 3 and 4 (located on the eastern side of the plain) intersect the San Benedetto dei Marsi-Gioia dei Marsi Fault.

3.4.1. Site 2

The site 2 trench exposes a lacustrine succession that mainly consists of Holocene clayey-silt layers (fig. 7). A single fault displaces these sediments, as well as another channel and its filling sediments, up to the base of the ploughed soil. Surveys along the walls of the long aqueduct trench located in the southwestern zone of the basin (a in fig.1) indicate that this channel, based on its stratigraphic position, was part of the Roman hydraulic works (similar hydraulic works of Roman age are reported for the northern side of the basin by Agostini and Rossi, 1989). In addition to the deformations which affected the lacustrine succession before the excavation of the channel, fig. 7 indicates that at least two distinct deformation events affected the channel. Evidence for the first event is detectable along the two small splays of the main fault, which displaces unit 7 and the lower part of unit 8. Because this event affected the first lacustrine episode in the channel it occurred shortly after the cessation of the Roman hydraulic works, consistent with what observed at site 1 for the main drainage channel. The second event was responsible for the displacement of units 8 and 9, that is the sediments related to the last depositional event before the 19th century reclamation works. It appears reasonable that this deformation event is related to the 1915 earthquake.

3.4.2. Sites 3 and 4

An important chronological constraint for the pre-1915 event at sites 1 and 2 was discovered in the trench excavated across the San Benedetto dei Marsi-Gioia dei Marsi Fault (site 3 in fig. 1) on the eastern side of the Fucino Plain. At this location a peat level was found which clearly overlies the colluvial and lacustrine sediments predating the Roman reclamation (Galadini *et al.*, 1996). This level represents the first evidence of the «new» lake at its natural level after the Roman hydraulic works, therefore it formed approximately during the same period as level E at site 1 and level 7 at site 2. Radiocarbon dating of this peat gave an age of 1450 ± 100 years B.P. and subsequent calibration by means of CALIB 3.0 (Stuiver and Reimer, 1993) yielded an age interval of 426-782 A.D. (considering the 2σ value; table I).

In one of the trenches excavated by Michetti *et al.* (1996) across the San Benedetto dei Marsi-Gioia dei Marsi Fault at site 4, a peat level was found at the same stratigraphic posi-

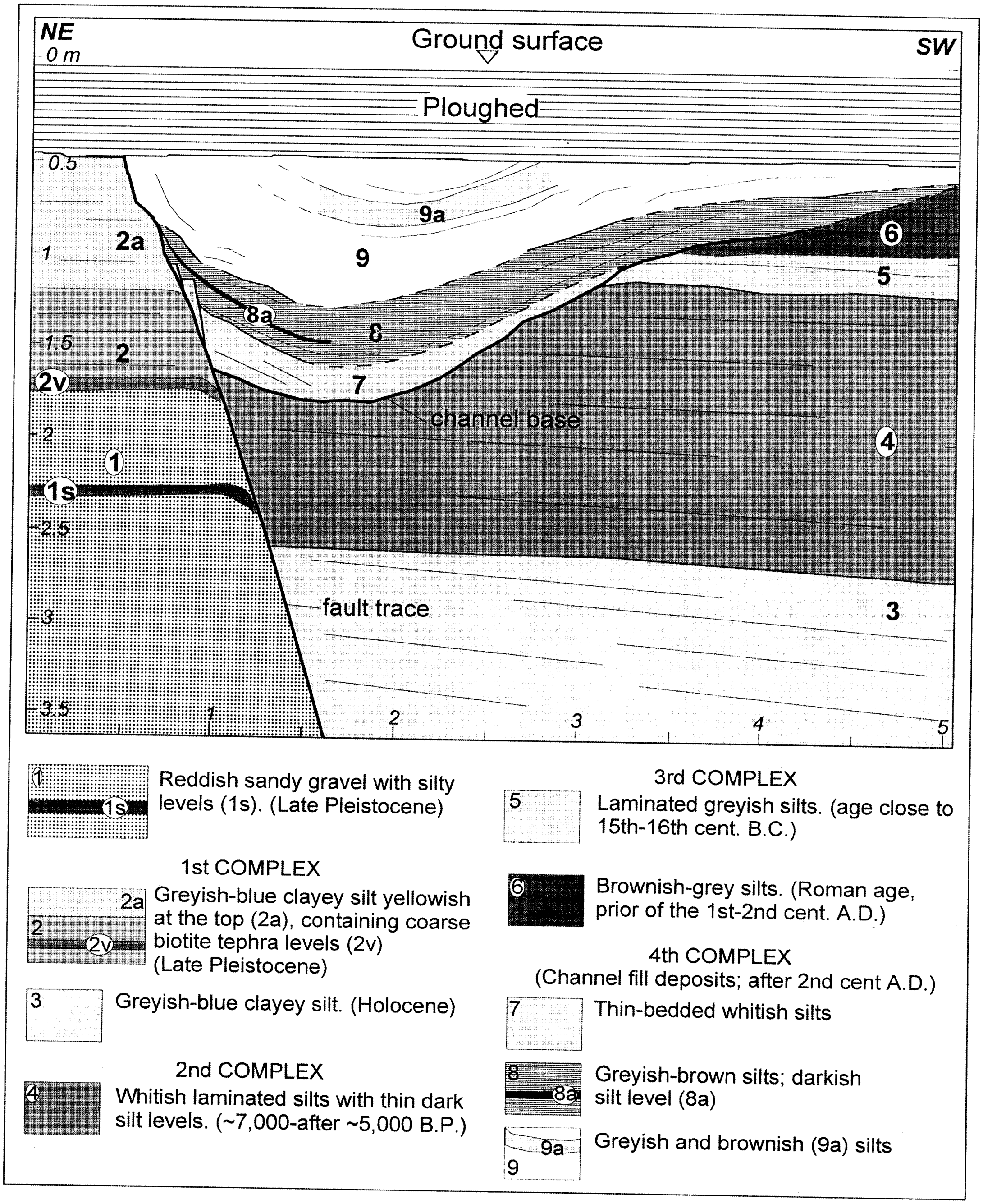

Fig. 7. Schematic section corresponding to the southeastern wall of the site 2 trench (site location in fig. 1). The distinction of the different sedimentary complexes is related to fig. 5.

Table I. Radiocarbon dates and calibrated radiocarbon dates obtained using CALIB 3.0 (Stuiver and Reimer, 1993). Dating of sample «a» was made by the CRAD laboratory in Udine (Italy). Date «b» is from Michetti *et al.* (1996). The 2σ ranges of the calibrated ages were used in this study.

	Laboratory age		Calibrated age ranges obtained from intercepts		Calibrated A.D. age ranges from probability distribution	
Sample		Half time correction	B.P.	A.D.	% area enclosed 68.3 (1σ)	95.4 (2σ)
a	1450 ± 100	1409 ± 100	1303	647	541-694	426-782
b	1375 ± 75	-	1292	658	599-774	534-886

tion as the peat of site 3. Radiocarbon dating of this peat gave an age of 1375 ± 75 years B.P. that yielded a calibrated age of 550-790 A.D. on the basis of CALIB (Stuiver and Reimer, 1986). Re-calibration of this date for this study by means of CALIB 3.0 (Stuiver and Reimer, 1993) yielded a new calibrated age of 534-886 A.D. (table I).

A comparison of the two dates obtained for the «new»-lake peat at sites 3 and 4 (see table I) indicates that the lake reached its natural level sometime between the beginning (at least) of the 6th century and the end of the 8th century. These results are in good agreement with historical accounts that indicate that the drainage channels ceased to operate at least during the 6th century.

3.5. *Geological constraints on the first deformation of the Roman channels*

The deformation related to the pre-1915 event at sites 1 and 2 affected the sedimentary succession up to the first lacustrine sediments after the Roman reclamation works; therefore the older date of the peat at sites 3 and 4 (the 6th century) represents the lowest chronological limit for this event. Paleoseismological data by Michetti *et al.* (1996) make it possible to constrain the upper chronological limit of this event as just after the deposition of the peat level. If this hypothesis is correct, this event occurred prior to the 9th century A.D.

The first event responsible for the displacements of the Roman hydraulic works thus occurred between the 6th and 9th centuries A.D.

It must be noted, however, that only a thin layer of post-Roman-drainage lacustrine sediments is involved in this deformation, despite the fact that the sediments were deposited inside the channels, where the sedimentation rate would have been much higher. This observation, together with the historical data which point out that the lake was likely at its natural level during the 6th century (probably before), indicates that the first displacement affecting the Roman channels probably occurred closer to the 6th than to the 9th century.

Considering that this is the same event reported by Michetti *et al.* (1996), we will adopt the same name used by these authors, *i.e.* the High Middle Age event (HMAE).

4. The age of the HMAE

The issue of defining the age of the HMAE requires an introduction into the seismicity of Rome, as historical record of this city has greatly enriched the seismic record of Central Italy. This is obviously linked to the long historical traditions of Rome as a political, religious and cultural centre and to the abundance of monuments for which detailed macroseismic information is sometimes available (Molin and Guidoboni, 1989; Molin *et al.*, 1995).

4.1. *Historical and archaeological data on earthquakes in Rome*

The 1915 earthquake, whose epicentral area was located less than 100 km east of Rome, was responsible for damage to city structures and monuments (for a review see Molin *et al.*, 1995). In particular, Molin *et al.* (1995) attributed an intensity of VI-VII (MCS) in Rome.

Data reported in Galadini *et al.* (1996) indicate that the faults reactivated at surface in the 1915 event also slipped during the HMAE (with almost the same vertical displacement). Taking into account available data it is possible to hypothesize that the two events were quite similar.

Based on this similarity it is possible to assume that the HMAE also caused significant damage in Rome. This idea is supported if one considers that a clear relationship exists between strong Central-Apennine earthquakes and high intensities in Rome, as shown in fig. 8.

As for the documented events which occurred in Rome between the 6th and the 9th centuries (approx. 508 A.D.; 618 A.D.; 801 A.D.; 847 A.D.) it is necessary to stress that knowledge about Italian seismicity for this period is largely incomplete. This is clearly linked to a «deficit» of historical sources (for a detailed analysis see Guidoboni *et al.*, 1994), and thus it is not possible to completely exclude the possibility that a strong earthquake occurred in the Fucino area on an unknown date, such as the HMAE, whose effects were not recorded in historical sources.

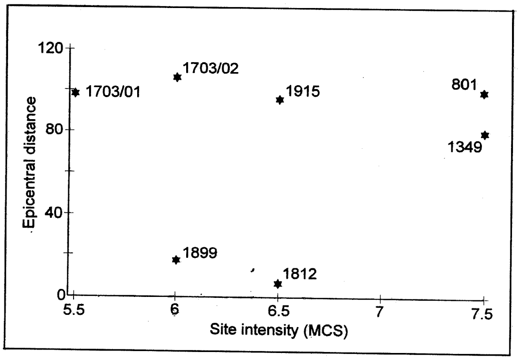

Fig. 8. Epicentral distances from Rome for earthquakes with intensities (in Rome) equal or greater than 5.5 MCS.

4.1.1. The earthquake which occurred immediately before 508 A.D.

This event is recalled on two memorial stones in the Colosseum in Rome (fig. 9) as an «*abominandi terraemotus*» (frightful earthquake). It was responsible for severe damage to the Colosseum which was partly restored during the consulate of *Decius Marius Venantius Basilius* (for archaeological details regarding seismic damage to the Colosseum see Priuli, 1985, 1986; Rea, 1993; Conforto and Rea, 1993; for seismological aspects see Croci *et al.*, 1995; Moczo *et al.*, 1995). Because the age of the consulate is not unequivocally known (484 A.D. or 508 A.D.), the earthquake was tentatively related to a time shortly before one of these dates (Guidoboni *et al.*, 1994; Molin *et al.*, 1995; Boschi *et al.*, 1995); recent archaeological data on the Colosseum (Rea 1993; Rea, personal communication) indicate that the event occurred closer to the more recent date.

4.1.2. The 618 A.D. earthquake

Nothing is known about the area where the earthquake of the 6th? of August, 618 originated, nor are data about damage available (Guidoboni *et al.*, 1994; Molin *et al.*, 1995). Nevertheless Gabucci *et al.* (1989), in a preliminary report on the archaeological excavations of the *Hilarian Basilica* in Rome, tentatively related the collapse of the walls to the earthquake of 618 A.D. This hypothesis is, however, no longer considered valid taking into account more recent archaeological data on this site which point to collapse of the walls at the beginning of the 6th century (Carignani, personal communication).

Fig. 9. Memorial stones located at the northern entry of the Colosseum in Rome which relate to the restorations of the Colosseum by *Decius Marius Venantius Basilius*, in 508 A.D., after an «abominandi terraemotus» (frightful earthquake).

4.1.3. The 801 A.D. earthquake

A strong earthquake on April 29th, 801 A.D. was responsible for damage to historical buildings in Rome. In particular, the collapse of the roof and damage to the external portico of the *San Paolo Basilica* is mentioned in historical sources (see also Lanciani, 1918), and the event may also have caused the collapse of the *Santa Petronilla church* (de Rossi, 1874; Guidoboni *et al.*, 1994). Regarding the location of this earthquake, a main historical source reports the «collapse of towns and mountains», probably meaning that major damage occurred within the Apennine chain (Molin and Guidoboni, 1989; Guidoboni *et al.*, 1994; Molin *et al.*, 1995; Boschi *et al.*, 1995).

4.1.4. The 847 A.D. earthquake

Regarding the event which occurred between April 10th and August 31st, 847 (Guidoboni *et al.*, 1994), it is not clear if it was responsible for the extensive damage and subsequent neglect of the church of *S. Maria Antiqua* in Rome (Hurst *et al.*, 1985; Budriesi, 1989 and reference therein), as no historical data are available about damage in Rome due to this earthquake.

Taking into account the historical record and available archaeological data, the events which occurred around 508 A.D. and in 801 A.D. have the characteristics of strong Central-Apennine earthquakes that may have been centred within the Fucino Plain. Knowledge about the 618 A.D. and 847 A.D. events is too little to assess the origin and impact of these two earthquakes on Rome.

4.2. *Archaeological data related to earthquakes in the Fucino basin and surrounding areas*

Among the possible archaeological indications of seismicity during the studied period, Mertens (1969, 1989) observed evidence of destruction during the excavation of the ancient town of Alba Fucens (northern side of the Fucino basin, see fig. 1) that he related to an earthquake. After the catastrophic event survivors lived in provisional huts and the lime for buildings, when used, was obtained from fragments of marble sculptures. As for the age of the catastrophe the discovery by the author of coins of Constans II (346-361) and Valens (364-367), found in the levels immediately overlying the road, indicates that the destruction did not occur before the end of the 4th century. Considering that the circulation of coins of this age is known to have occurred until at least the 8th century (Cesano, 1913; Morrisson, 1980; Reece, 1984; Molinari, 1994; Molinari, personal communication), the age of the coins determines the *post quem* date of the event. Obviously the probability of the occurence of the event diminishes going from the end of the 4th century to the end of the High Middle Age.

Archaeological data indicating an event during the 9th century are not found in the studied area, as the only other indications are related to church reconstructions during the 13th century (Ricci, 1915; Delogu, 1969; Mancini *et al.*, 1992).

If the damage observed by Mertens (1989) was seismically induced and if the earthquake was the one responsible for the first displacement of the Roman channels, it is more likely that the event occurred around 508 A.D. or in 618 A.D. rather than in 801 A.D. or 847 A.D. In this case archaeological data regarding the event would be in agreement with geological data (see section 3.4.3).

The available data can be summarized as follows:

1) paleoseismological data (*i.e.*, the displacement of Roman drainage channels in the Fucino Plain) point to a paleoseismic event which occurred between the 6th and 9th centuries;

2) geological data (*i.e.*, the deformation of the first sediments deposited after the Roman reclamation works) plus historical (*i.e.*, the history of the lake) and archaeological indications (*i.e.*, destruction of Alba Fucens) point to an occurrence probably closer to the 6th century than to the 9th century;

3) taking into account point (2) and the seismicity of Rome between the 6th and the 9th century A.D. (section 4.1) it is possible to hypothesize that the earthquake responsible for the displacement of the Roman channels was that which occurred immediately before 508 A.D. or subordinately (considering the lack of historical information about damage in Rome) that which occurred in 618 A.D. Obviously this conclusion is based on probabilities, and as such the possibility that the event responsible for the studied paleo-archaeoseismic deformation was the 801 or 847 A.D. one (or other events not documented) cannot be excluded.

5. Conclusions

A paleoseismological study in the Fucino Plain (Central Italy) has identified the first case of coseismic faulting of archaeological remains in Italy; this case adds to those reported in other parts of the world (Neev *et al.*, 1973; Trifonov, 1978; Kamoun, 1984; Buchun *et al.*, 1986; Stiros, 1988b; Altunel and Hancock, 1993; Barka, 1995).

The study of the coseismic displacements of the Fucino Plain archaeological remains, through the use of standard paleoseismological techniques, permitted the deformations to be associated with an event which occurred between the 6th and 9th century A.D. (High Middle Age event). Geological, archaeological and historical data as a whole indicated that this earthquake, responsible for the displacement of Roman channels, may have been the event which occurred immediately before 508 A.D. or, subordinately, in 618 A.D.; the former was responsible for significant damage to the Colosseum in Rome, however historical knowledge about both earthquakes is largely incomplete and the epicentral area is unknown.

If correct, this hypothesis would make it possible to define the source of one of two unlocated subrecent events of the Italian historical record.

The catastrophic 1915 earthquake in Central Italy ($M_s = 7.04$) also originated in the Fucino area, due to the activity of a well-known seismogenetic structure (*e.g.*, Serva *et al.*, 1986; Ward and Valensise, 1989; Galadini *et al.*, 1995). Extensive paleoseismological research (Galadini *et al.*, 1996) has indicated that the High Middle Age and 1915 events are characterized by displacements along the same structures and with similar offsets. This shows not only that these earthquakes were produced by the same seismogenetic structure, but also that the High Middle Age event represent an ancient «twin» of the 1915 earthquake.

A direct consequence of this consideration, if the hypothesis regarding the date of the High Middle Age event is correct, would be a precise evaluation of the time interval (about 1300-1400 years) between the last two earthquakes having similar effects along the Fucino seismogenetic structure.

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