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ENEA RADIOCARBON MEASUREMENTS I

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ABSTRACT. This paper includes determinations of archeological and geological samples from different sites in central Italy performed at the Ente per le Nuove Tecnologie l'Energia e l'Ambiente (ENEA) Radiocarbon Laboratory. This laboratory has been in operation since 1985 at the ENEA Bologna Research Center.

INTRODUCTION

In this report, we present dating of archaeological and geological samples performed since 1990 in the radiocarbon laboratory of the ENEA (Ente per le Nuove Tecnologie, l'Energia e l'Ambiente). Sample preparation, liquid scintillation counting procedure, and processing of data are briefly described. Pretreatment of soil, charcoal, wood, and peat is a standard acid-base procedure using 18% HCl and 2M KOH at boiling temperature. The method of dating is based on benzene synthesis and liquid scintillation counting (LSC) using a scintillation cocktail of 15 butyl-PBD/mL benzene (Gupta and Polach 1985). We used cylindrical Teflon-S® vials designed by ISTA Ltd. (Faenza, Italy) with Delrin caps sealed with epoxy resin. The 9-mL vials are 50 mm high and 27 mm in outer diameter with a 12-mm-thick Teflon base. ANU sucrose and Carrara marble are used as modern and background standards, respectively. Age calculations are based on the Libby half-life of 5568 yr and are expressed in ^{14}C years relative to AD 1950 as the reference year. Ages and standard deviations (1-σ error) of samples are adjusted for stable isotope fractionation to a normalized concentration ratio ($\delta^{13}C = -25‰$) according to the recommendations reported by Stuiver and Polach (1977), using the default $\delta^{13}C$ values. Calibrated ages are calculated from rounded ^{14}C conventional ages by using the program OxCal v 3.9 (Bronk Ramsey 2003) with 1-σ error (68.2% confidence level). When several calendar age ranges are obtained, the probability for each interval is given. Probabilities less than 5% are omitted.

ARCHAEOLOGICAL SAMPLES

Flaminia Militare Series

Samples were collected from the old Roman street Flaminia Militare (Figure 1), which connected Bologna with Fiesole (near Florence) during the Roman Empire. Samples were submitted in 1986–1994 by Agostini (ENEA-104, ENEA-108) and Fedeli and Longo (ENEA-42, ENEA-43).

ENEA-42. Longo 3 **1320 ± 80**
Wood from San Benedetto Val di Sambro (Bologna) (44°12′N, 11°08′E), 590 m asl, 1.0 m depth (cal AD 640–810, 68.2%).

ENEA-43. Longo 4 **2640 ± 70**
Wood from Poggio Castelluccio (44°06′N, 11°23′E), 1110 m asl, 0.9 m depth (cal 900–760 BC, 68.2%).

ENEA-104. Agostini 5 **3510 ± 250**
Charcoal from Poggiaccio (44°09′N, 11°22′E), 1190 m asl, 0.4 m depth (cal 2200–1500 BC, 68.2%).

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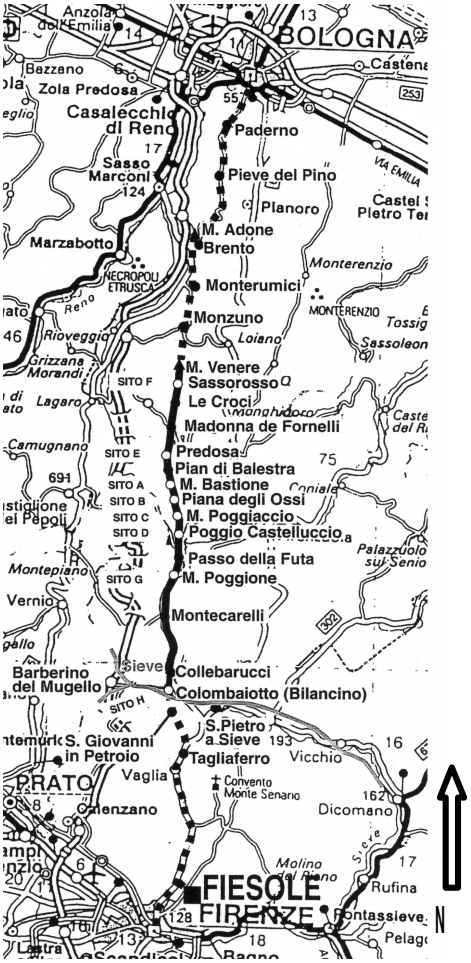

Figure 1 Sample sites along the Flaminia Militare road

ENEA-108. Agostini 8 **1290 ± 350**
Charcoal from Piana degli Ossi (44°12′N, 11°25′E), 1090 m asl, 1.9 m depth (cal AD 400–1200, 68.2%).

ENEA-139. PDO89-SG C-US 24 **1460 ± 65**
Charcoal from Piana degli Ossi, 1 m depth (cal AD 540–660, 68.2%).

ENEA-143. PDO89-SG A-US 51 **650 ± 125**
Charcoal from Piana degli Ossi, 5 m depth (cal AD 1250–1430, 68.2%).

ENEA-148. BPC-SG C-US 303 **1880 ± 110**
Soil from Poggio Castelluccio, 0.4 m depth (cal AD 1–260, 65.7%).

ENEA-149. SG A-US 210 **3160 ± 110**
Soil from Poggio Castelluccio, 1.2 m depth (cal 1530–1260 BC, 65.2%).

ENEA-150. SG A-US 210 **2430 ± 55**
Charcoal from Poggio Castelluccio, 1 m depth (cal 760–680 BC, 20.8%; 550–400 BC, 44.8%).

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ENEA-151. PDO89-SG A-US 60 **740 ± 55**
Charcoal from Piana degli Ossi, 4.5 m depth (cal AD 1220–1300, 68.2%).

ENEA-152. SG C-US 0 **790 ± 205**
Soil from Poggio Castelluccio, 0.3 m depth (cal AD 1020–1330, 61.0%; AD 1340–1400, 7.2%).

ENEA-381. PONTE 2 **910 ± 60**
Wood from the bridge Colombaiotto, Barberino del Mugello (44°00′N, 11°15′E) (cal AD 1030–1190, 68.2%).

ENEA-396. PONTE 2 **2820 ± 40**
Wood from the bridge Colombaiotto, Barberino del Mugello (cal 1010–900 BC, 68.2%).

Comment: Analysis confirmed that the Flaminia Militare road connecting Bologna with Fiesole during the Roman Empire was designed by the Etruscans and manufactured, together with the Romans, before 200 BC. Published in Agostini and Santi (2000).

GEOLOGICAL SAMPLES

Mount Cavallo Series

Samples from Mount Cavallo (41°41′N, 13°56′E; Figure 2), 1720 m asl, central Apennines, were collected and submitted in 1990 by C Giraudi, ENEA (Casaccia Research Center), Rome.

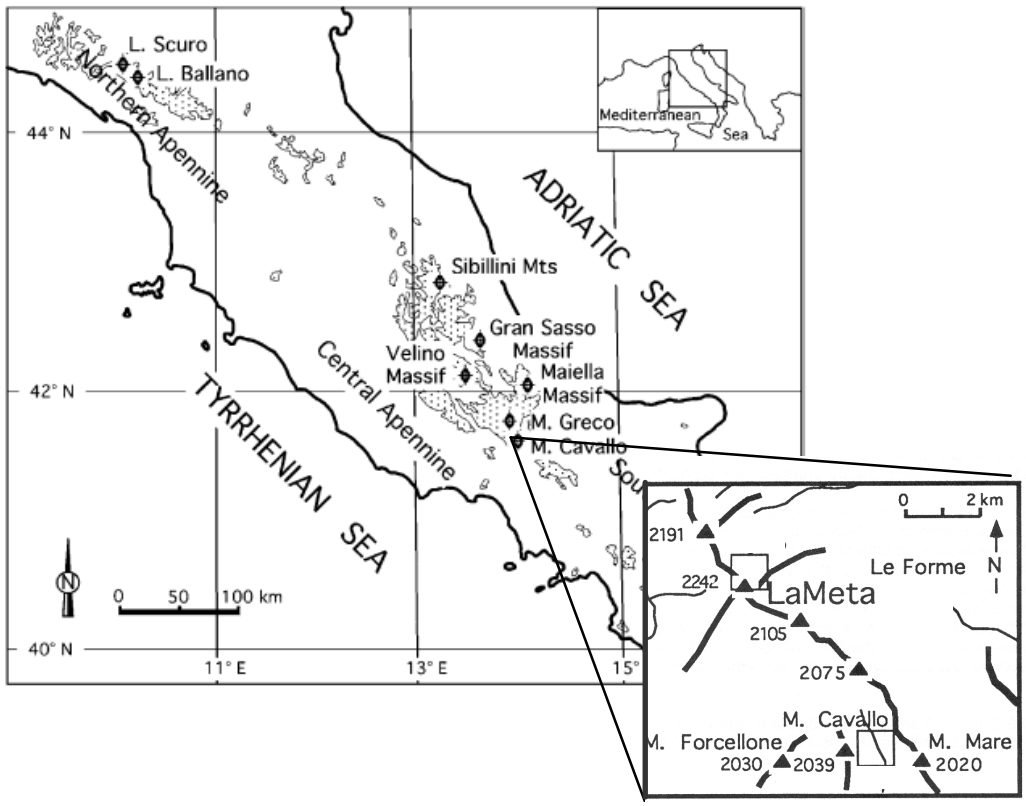

Figure 2 Mount Cavallo sample sites

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ENEA-175. CAV 1 **4400 ± 60**
Wood from alluvial sediments, 3.6 m depth (cal 3260–2910 BC, 68.2%).

ENEA-176. CAV 2 **2750 ± 110**
Peat from alluvial sediments, 3.3 m depth (cal 1040–800 BC, 68.2%).

Comment: Dating of sandy-silty alluvial sediments was conducted in order to define the main climatic-environmental scenarios due to Holocene environmental changes in the central Apennines. Published in Giraudi (1997).

Pescasseroli Series

Samples from Pescasseroli (41°47′N, 13°46′E; Figure 3), National Park of Abruzzo, central Apennines, were collected and submitted in 1991–1992 by C Giraudi.

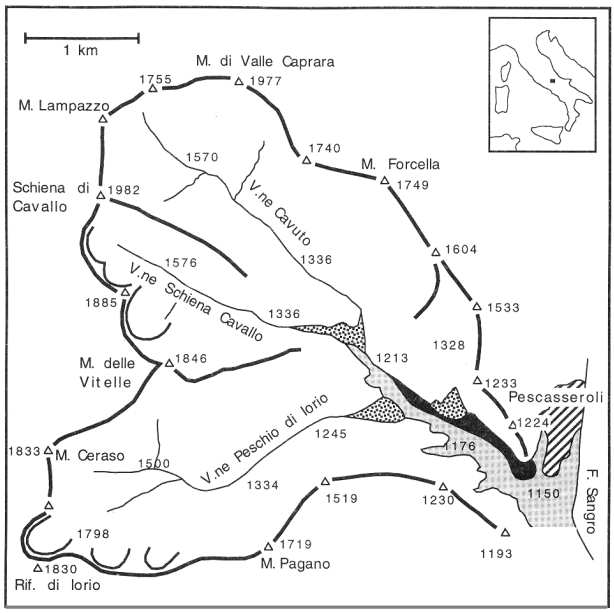

Figure 3 Pescasseroli sample sites

ENEA-244. PCA 1 **3770 ± 80**
Soil, 1.3 m depth (cal 2310–2030 BC, 68.2%).

ENEA-256. PESA 1 **6900 ± 90**
Soil, 4.0 m depth (cal 5880–5660 BC, 68.2%).

ENEA-257. PESA 3 **8990 ± 80**
Soil, 4.5 m depth (cal 8290–7970 BC, 68.2%).

Comment: The analyses were part of stratigraphical studies on the lower valley of Peschio di Iorio in Abruzzo in order to define the depositional, erosive, and pedogenetic phases that occurred after the last glacial maximum in this area. Published in Giraudi (1997).

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Campo Imperatore Series

Samples from Campo Imperatore and Gran Sasso Massif (41°47′N, 13°46′E; Figure 4), central Apennines, were collected and submitted in 1990–1992 by C Giraudi.

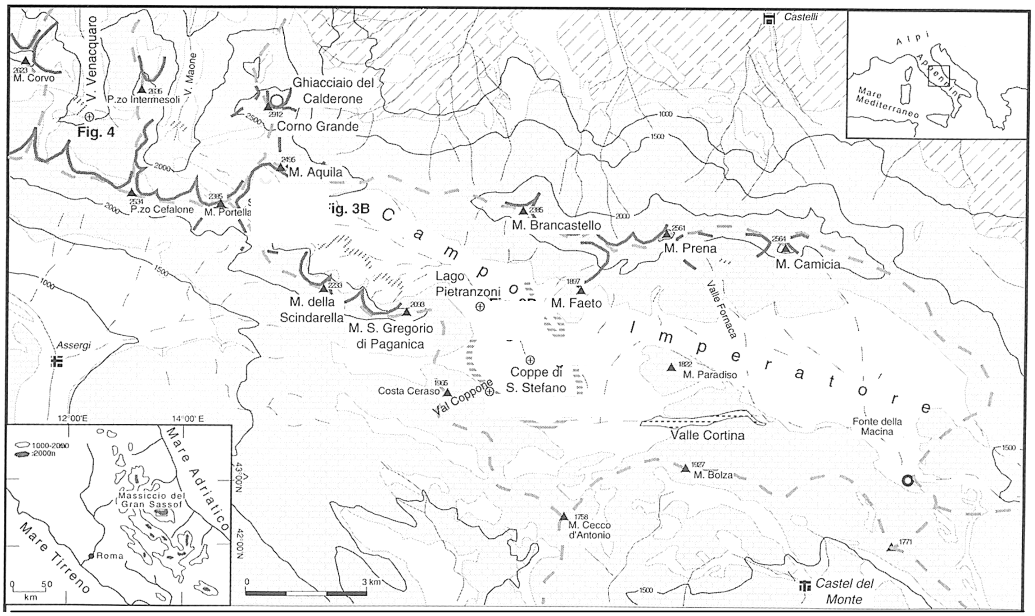

Figure 4 Campo Imperatore sample sites

ENEA-177. X 3 **3740 ± 90**
Soil (lacustrine sediments), 1.0 m depth, from an enclosed depression on the rock glaciers located on the southern slope of Mount Aquila (1910 m asl) (cal 2290–1980 BC, 68.2%).

ENEA-179. Y 1-2 **31,500 ± 550**
Soil, 9.0 m depth, from deposit forming the Fornaca Valley alluvial fan.

ENEA-232. C.I. FONT. 1 **12,100 ± 100**
$\delta^{13}C = -27.5 \pm 0.2$
Soil, 4.0 m depth (cal 13,000–11,800 BC, 68.2%).

ENEA-233. C.I. FONT. 2 **5640 ± 60**
Soil, 1.5 m depth (cal 4550–4360 BC, 68.2%).

ENEA-237. C.I. FONT. 3 **6090 ± 70**
Soil, 3.5 m depth (cal 5210–4850 BC, 68.2%).

ENEA-250. CIS 6 **22,350 ± 300**
Soil (lacustrine sediment), 3.5 m depth, from Coppone Valley (1657 m asl).

ENEA-251. CIS 3 **22,680 ± 530**
Soil (lacustrine sediment), 5.3 m depth, from Coppone Valley (1657 m asl).

ENEA-252. CIS 2 **21,050 ± 240**
Soil (lacustrine sediment), 2.0 m depth, from Coppone Valley (1657 m asl).

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ENEA-253. CIT 7 **5420 ± 80**
Soil, 1.5 m depth, from the alluvial fan on the southwest slope of Mount Prena (1700 m asl) (cal 4350–4050 BC, 68.2%).

ENEA-254. CIT 1 **21,450 ± 250**
Soil, 6.0 m depth, from the deposit forming the Fornaca Valley alluvial fan.

ENEA-285. CIFA 1 **5200 ± 60**
Soil, 1.0 m depth, from the alluvial fan on the southwest slope of Mount Prena (1700 m asl) (cal 4220–3950 BC, 68.2%).

ENEA-286. CIFA 2 **7060 ± 60**
$\delta^{13}C = -16.6 \pm 0.1$
Soil, 1.0 m depth, from the upper regions of Fornaca Valley (1750 m asl) (cal 6000–5840 BC, 68.2%).

ENEA-240. CAMO 1 **21,850 ± 150**
$\delta^{13}C = -23.0 \pm 0.1$
Soil, 3.5 m depth, from Castel del Monte (1300 m asl), a few kilometers from the eastern edge of Campo Imperatore (cal 6000–5840 BC, 68.2%).

Comment: Dating the lacustrine sediments of Gran Sasso Massif established that they are the same age as other sediments of ephemeral lakes found on other massifs in central Italy. Furthermore, the sediments found on the massif allowed us to identify several ephemeral lakes in this zone that could be dated to the last glacial maximum (LGM), the late-glacial, and the Holocene. Published in Giraudi (1998).

Pezza Plain Series

Samples from Pezza Plain (42°11′N, 13°27′E; Figure 5), 1450–1530 m asl, central Apennines, were collected and submitted in 1991–1993 by C Giraudi.

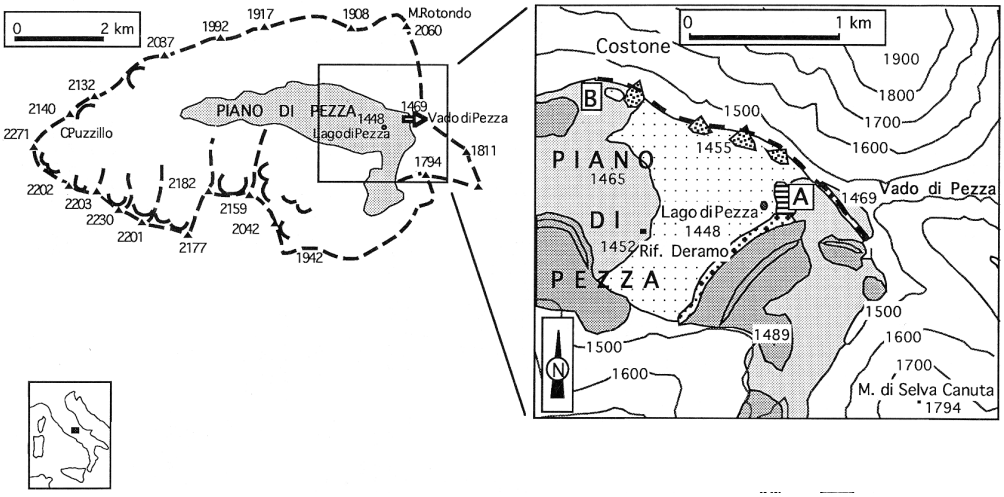

Figure 5 Pezza Plain sample sites

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ENEA-287. PP 1 **5790 ± 70**
Soil, 4.0 m depth, from Pezza Plain (zone A in Figure 5) (cal 4720–4540 BC, 68.2%).

ENEA-288. PP 2 **3260 ± 50**
$\delta^{13}C = -25.7 \pm 0.1$
Soil, 3.0 m depth, from Pezza Plain (zone A in Figure 5) (cal 1610–1450 BC, 68.2%).

ENEA-289. PP 3 **3180 ± 70**
Humic fraction of organic soil (aeolian deposit), 2.0 m depth, from Pezza Plain (zone A in Figure 5) (cal 1530–1320 BC, 68.2%).

ENEA-290. PP 4 **1580 ± 70**
Soil, 1.2 m depth, from Pezza Plain (zone A in Figure 5) (cal AD 410–570, 68.2%).

ENEA-291. PP 6 **3400 ± 50**
$\delta^{13}C = -25.4 \pm 0.1$
Soil, 1.0 m depth, from Pezza Plain (zone B in Figure 5) (cal 1770–1610 BC, 68.2%).

ENEA-292. PP 8 **3650 ± 70**
Humic fraction of organic soil, 0.9 m depth, from Pezza Plain (zone B in Figure 5) (cal 2140–1920 BC, 68.2%).

Comment: Stratigraphic study of the late-Pleistocene and Holocene sediments allowed the identification of 5 lacustrine formations and of the period of maximum level. Published in Giraudi (1997).

Fucino Plain Series

Samples from Fucino Plain (41°59′N, 13°32′E; Figure 6), central Italy, were collected and submitted in 1991–1994 by C Giraudi.

ENEA-238. VEMA 4 **11,650 ± 70**
Charcoal, 5.0 m depth, from Venere dei Marsi (cal 11,870–11,510 BC, 68.2%).

ENEA-258. SAVE 2 **17,950 ± 180**
Soil (colluvial sediment), 6.2 m depth, from Fucino (cal 19,800–18,950 BC, 68.2%).

ENEA-267. TR A 1 **6880 ± 120**
Charcoal, 1.0 m depth, from Trasacco (cal 5880–5630 BC, 68.2%)

ENEA-331. FUS 1 **43,400 ± 1400**
Peat, 8.0 m depth, from Fucino.

ENEA-332. FUS 3 **19,100 ± 650**
Soil (lacustrine sediment), 3.0 m depth, from Brecciago Mount (1974 m asl) (cal 21,800–20,000 BC, 68.2%).

ENEA-345. CAVE 1 **10,750 ± 100**
Soil (lacustrine sediment), 4.0 m depth, from Fucino (cal 11,020–10,690 BC, 68.2%).

ENEA-354. CASCHI 5 **32,500 ± 500**
Soil, 7.0 m depth, from Fucino.

ENEA-383. CA.ROM.2 **2980 ± 70**
Peat, 0.8 m depth, from Fucino (cal 1370–1050 BC, 68.2%).

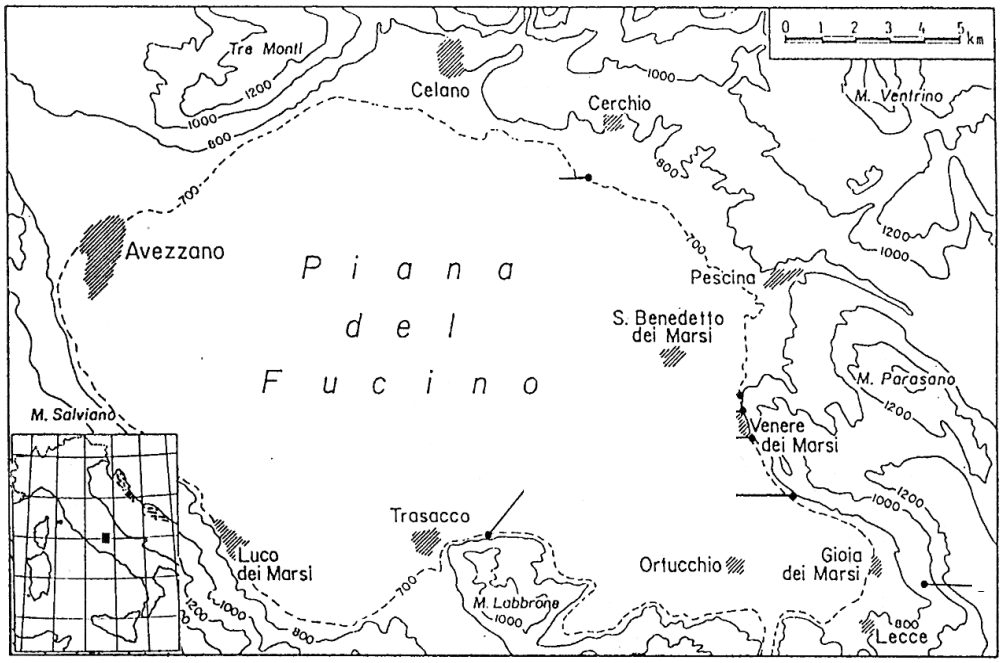

Figure 6 Fucino Plain sample sites

ENEA-384. C.AN. 1 **2970 ± 70**
Peat, 0.7 m depth, from Fucino (cal 1310–1050 BC, 68.2%).

ENEA-385. FU.AQ. 1 **11,500 ± 460**
Soil, 2.5 m depth, from Fucino (cal 12,200–11,000 BC, 68.2%).

ENEA-386. FU.AQ. 2 **13,500 ± 120**
Soil, 3.0 m depth, from Fucino (cal 14,550–13,950 BC, 68.2%).

ENEA-387. FU.VET. 7 **6170 ± 140**
Soil, 1.5 m depth, from Fucino (cal 5300–4940 BC, 68.2%).

ENEA-388. TR-1-1 **20,610 ± 200**
Soil (lacustrine sediment), 4.0 m depth, from Fucino.

ENEA-389. TR-1-3 **9910 ± 60**
Soil (lacustrine sediment), 2.0 m depth, from Fucino (cal 9600–9250 BC, 68.2%).

ENEA-390. TR-2-1 **23,450 ± 280**
Soil (lacustrine sediment), 5.0 m depth, from Fucino.

ENEA-391. TR-2-2 **12,100 ± 50**
Soil (lacustrine sediment), 2.0 m depth, from Fucino (cal 13,100–11,800 BC, 68.2%).

ENEA-392. TRS **17,400 ± 160**
Soil, 3.0 m depth, from Fucino (cal 19,150–18,350 BC, 68.2%).

ENEA-393. FU.AC 1 **5060 ± 90**
Soil, 1.0 m depth, from Fucino (cal 3970–3770 BC, 68.2%).

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Comment: Dating the Fucino Plain lacustrine sediments allowed us to define the geochronology of the slope waste deposits. Furthermore, a chronological correlation between phases of scree accumulation and the decrease in water level of Lake Fucino was assessed; the correlation suggested that environmental changes were mostly linked to drier climatic periods.

CONCLUSION

Archaeological samples collected from Flaminia Militare confirmed that this road was manufactured and used by the Romans from 200 BC until the Middle Ages as indicated by the calibrated ages of the samples ENEA-143, -151, -152, and -381.

Different conclusions result from analyzing the geological samples collected at various sites in the central Apennines (central Italy). In particular, the climatic fluctuations of this area before and after the LGM were clearly assessed from dates of sediments found in several sites located near Gran Sasso Massif.

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