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ORIGINAL ARTICLE

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Economy and environment of Bronze Age settlements – Terramaras – on the Po Plain (Northern Italy): first results from the archaeobotanical research at the Terramara di Montale

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Abstract The paper presents a synthesis of the on-site archaeobotanical investigations of the Terramara di Montale, one of the most important sites of the Terramara cultural system which characterised the Po Plain in the Middle-Late Bronze Age (1650–1200 B.C.). Samples for pollen analysis and macroremains, including seed/fruit and wood/charcoal records, were collected from stratigraphic sequences and occupation levels during the excavations 1996–2001. The results permitted the reconstruction of the main characteristics of the landscape which at the onset of the Terramara rapidly passed from a natural, more forested landscape with mixed oak wood and conifers to a more open and anthropic landscape characterised by cereal fields, pastures and meadows. People felled oaks and other trees such as *Populus/Salix* and *Fraxinus* to make piles or walls for houses. Wood from these species was also recorded as charcoal in the hearths. Palynological and carpological data show that the inhabitants of the Terramara largely founded their economy on cereals (mainly *Triticum aestivum/durum*, *T. dicoccum* and *Hordeum vulgare*). They also grew a few legumes (*Vicia faba* var. *minor*, *Vicia* sp. and *Lens culinaris*). There was also grazing by domestic animals, mainly ovicaprines but also pigs and cattle, and these were fed exploiting wild plants such as *Carpinus*. In the paper the four main steps of the history of the Terramara are described (before the Terramara, the onset, the Terramara phase, the decline) during which both human influence and climatic changes were important. At the onset of the Terramara (around 1600 B.C.) a warm and possibly dry phase occurred. The intense use of the territory and a climatic deterioration at around 1300 B.C. might have triggered the decline of the Terramara di Montale.

Keywords Archaeobotany · Terramara · Bronze Age · Northern Italy · Environmental change · Human impact

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Introduction

During the Middle Bronze Age (1650–1350 B.C.), the central Po Plain was settled by an important archaeological culture with large villages named Terramaras (Fig. 1). Settlements consisted of fortified villages surrounded by an embankment and a ditch. They were 1–2 ha in area in the earlier phases and were subsequently enlarged to up to 20 ha in the final phases during the Late Bronze Age (ca. 1350–1200 B.C.). The great socio-economic system of the Terramaras was based on a cooperative organisation and a complex territorial association of villages, which was organised in a hierarchic system with both hegemonic and subordinate sites during the Late Bronze Age. The estimated number of people in the Terramara area around the 14th–13th century B.C. was about 150,000. At the end of the Late Bronze Age (ca. 1200 B.C.) this civilisation vanished, possibly through a combination of climatic, ecological and socio/economic causes (Bernabó Brea et al. 1997).

The Emilia Romagna region, which covers a large part of the Po Plain, is rich in Terramaras (Fig. 1). So far archaeologists have discovered more than 220 sites (Cremaschi

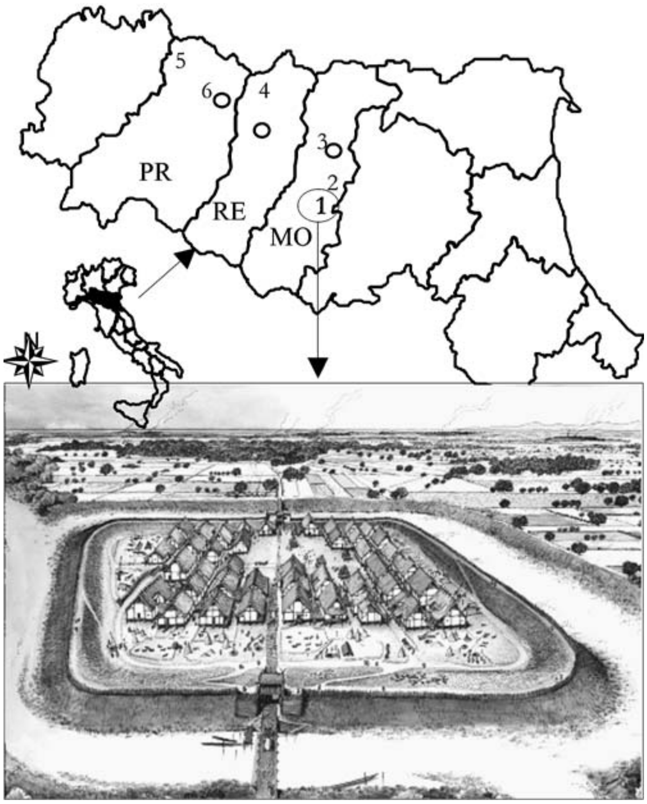


Fig. 1 Map showing the location of those Terramaras with archaeobotanical studies in three provinces of Emilia Romagna, North Italy. The reconstruction of the Terramara di Montale (site 1) was drawn by R. Merlo (modified from Cardarelli 2004); MO, Modena; (1) Montale, (2) S. Ambrogio, (3) Tabina di Magreta. RE, Reggio Emilia; (4), Terramara di S. Rosa. PR, Parma; (5) Castione Marchesi, (6) Parma

1997). Of these, thirty-five lie in the province of Modena, on the borderline between plain and hills, not far from Montale. Despite the large number of sites, archaeobotanical investigations were carried out only at six Terramara sites (Table 1, Fig. 1).

The Terramara di Montale is one of the most important sites of the Middle-Late Bronze Age in Northern Italy. Its first excavation, directed by Carlo Boni, dates back to 1871. Some years before his death in 1894, the Terramara was almost completely destroyed by the extraction of organic material to manure fields, as occurred at other Terramaras. In the nineteen-eighties, the excavation was resumed and preliminary xylological analyses were carried out (Forlani 1988). In 1994, under the direction of A. Cardarelli, new multidisciplinary investigations promoted by the "Museo Civico Archeologico Etnologico" of Modena and the "Soprintendenza ai Beni Archeologici" of Emilia Romagna started on the site. Archaeological, stratigraphical, archaeobotanical and archaeozoological studies were carried out to reconstruct the natural and cultural landscape, the structure and organisation of the Terramara and the lifestyle of its inhabitants (Cardarelli 2004). The research included the analyses of pollen, seeds/fruits and woods/charcoals recorded on-site, i.e. mainly transported by humans and their animals. Despite the known problems in the interpretation of on-site pollen data for palaeovegetational/ palaeoecological reconstruction (Faegri and Iversen 1989; Behre and Jacomet 1991) such a reconstruction was attempted. This was done while carefully checking the independent interpretation of the diagram by a multidisciplinary approach and comparing the local (disturbed) diagram with others (mostly natural) available from the region. In fact about ninety sites were studied in Emilia Romagna, 62 being off-site profiles (Accorsi et al. 1999, and references therein). They show the evolution from a forested to a fairly open landscape during the Holocene. In the Subboreal, the cultural landscape began to be evident, especially in the increase in open areas and the spread of possibly cultivated plants, such as *Castanea*, *Juglans* and *Vitis*. Moreover, the comparison between off-site and on-site data, which also included some data from Terramaras, indicates that human groups generally settled in naturally open or cleared areas, mainly surrounded by deciduous oak woods.

A further aim of the archaeobotanical study presented here was to provide a scientific basis for the setting-up and structure of an archaeological park that was achieved in 2004. This is within the framework of the European Project 'Archeolive' and is linked with the "Pfahlbaumuseum Unteruhldingen" of

Table 1 List of the Terramaras with references for archaeobotanical data in Emilia Romagna, Northern Italy

Terramara	Province	Records	References
Tabina di Magreta	Modena	Pollen, seeds and fruits	Bertolani Marchetti et al. (1988), Bandini Mazzanti and Taroni (1988a, b)
Sant'Ambrogio	Modena	Seeds and fruits, wood	Bandini Mazzanti and Taroni (1988b), Forlani (1988)
Santa Rosa di Poviglio	Reggio Emilia	Pollen, seeds and fruits, wood and charcoal	Ravazzi et al. (1992), Ravazzi et al. (in press)
Castione Marchesi	Parma	Wood, seeds and fruits	Pigorini and Strobel (1864), partially revised by Rottoli (1988, 1997a)
Palafitta di Parma	Parma	Wood, seeds and fruits	Pigorini and Strobel (1864), partially revised by Rottoli (1988, 1997a)
Montale	Modena	Wood	Forlani (1988)

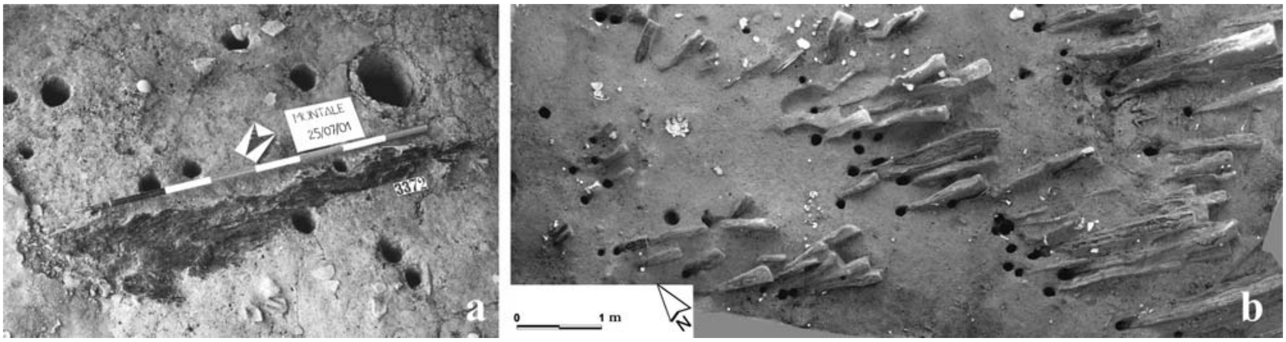


Fig. 2 Photographs of the excavation of the Terramara di Montale (modified from Cardarelli 2004): **a** charred trunk of oak at the base of Phase I; **b** holes and flattened wooden house piles at the base of Phase II

Lake Constance and the "Naturhistorisches Museum Wien".

The site

The Terramara di Montale (Lat. 44°30′N, Long. 10°55′E) is located in the centre of Montale, a small town in the province of Modena (Fig. 1). It lies in the Po plain at 71 m a.s.l. below the hill belt of the Tusco-Emilian Appennines. Originally the Terramara consisted of a village approx. 10,000 m^2 in extent (Fig. 1). This was situated on a natural hillock approximately 4 m high and surrounded by a defensive embankment with a base approximately 10 m wide and a ditch 40 m wide and 3 m deep filled by water from the nearby river. Based on other Terramara settlements and the demographic density inferred from the number of tombs in their necropolis, there were 30–40 houses and ca. 150 people (Cardarelli 2004). In 1996–2001 a stratigraphic excavation by the "Museo Civico Archeologico Etnologico" of Modena was carried out on an area of 45 m^2. The excavation enabled the recognition of the establishment of the village which was preceded by forest clearance through cutting, clearing and burning. Hundreds of house pile holes and a charred trunk, identified as oak (Fig. 2a), marked the bottom level of the Terramara (Fig. 2b).

Stratigraphy, chronology and preservation of the layers

Based on micromorphological analyses (Cremaschi 1997), the stratigraphic series at Montale, about 350–400 cm thick, was preliminarily subdivided from the bottom as follows (Fig. 3):

At the base is a hydromorphic palaeosol (natural soil; Layer 10). Above this are 4 geoarchaeological units comprising 9 layers (10 if 2a and 2b are counted separately) as below:

Unit 1 (Layer 9): A few cm thick, this is an anthropic deposit marked by pile holes and a high proportion of subfossil organic matter, characterised by high porosity, bioturbation and signs of low hydromorphy.

Unit 2 (Layers 8, 7, 6): This consists of floors made of burned soil (mainly laminated silt showing signs of hydromorphy and rich in subfossil organic matter), lying on wooden piles in part still preserved in their holes

Unit 3 (Layers 5, 4, 3): This mainly consists of hearth residues deposited on a heap and finely laminated silt, the latter testifying that it had not been reworked by humans

Unit 4 (Layers 2b, 2a): This consists of floors characterised by silt including lenses rich in subfossil organic matter and signs of bioturbation

At the top, there is a vertic soil (Layer 1) with mixed archaeological materials covered by recent material. A more detailed geoarchaeological study is in progress.

Chronology was based on archaeological dates and 8 radiometric dates (Oxford Radiocarbon Accelerator Unit) obtained from charcoal remains found within the four geoarchaeological units described above. The dates were calibrated using the OxCal 3.9 program (Table 2; 68% probability). They agree with the archaeological dates (Fig. 3). Archaeological chronology indicated that the Terramara was inhabited for about 350 years from 1600 to 1250 B.C., during the Middle (BM2A) and Late (BR1) Bronze Age. Eleven archaeological 'Terramara phases' were distinguished ranging from Phase I - 1600 B.C. at the bottom to Phase XI – 1300–1250 B.C. at the top, corresponding with the eight geoarchaeological layers 9 to 2 (Fig. 3). The main characteristics of the eleven phases are (Fig. 3; Table 2; Cardarelli and Labate 2004):

I (1605–1510 B.C.; 1605–1515 B.C.): First rectangular house, 9 m × 6.5 m, with a floor suspended on wooden piles, later removed by demolition and cutting.

II (1600–1450 B.C.): Second house of similar dimensions and again built on piles in the same place; later destroyed by fire.

III Third house on piles destroyed by fire.

IV Fourth house with a muddy and sandy floor, without piles; later destroyed.

V (1490–1320 B.C.): Furnace for metallurgical activity linked to the production of bronze tools.

VI (1495–1400 B.C.): Probably a new house, the fifth, of the same shape as that in phase IV was built.

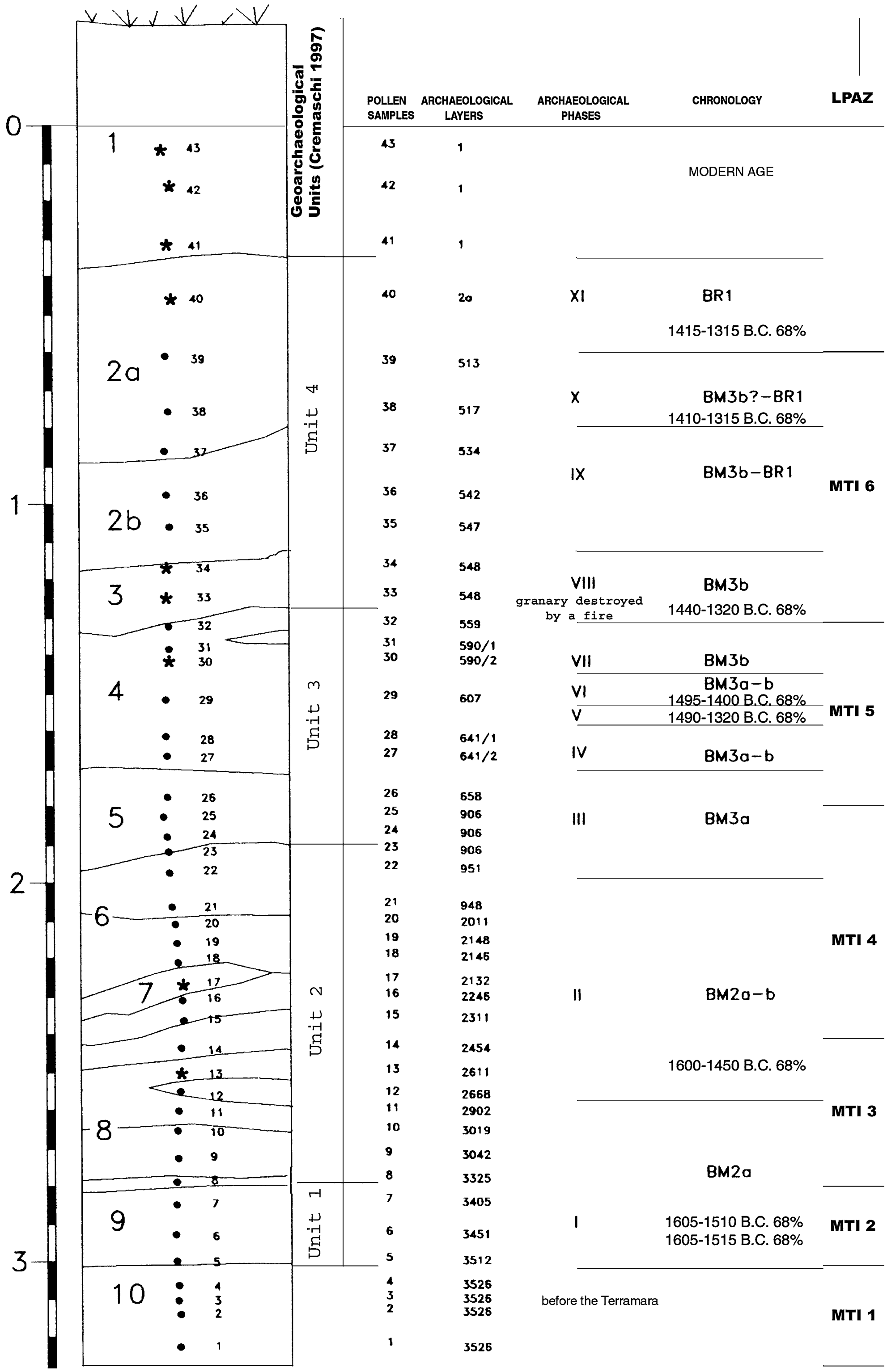


Fig. 3 Pollen sampling through the stratigraphic sequence of Profile I, with archaeological layers, chronology (Phases: the Terramara started in Phase I; Culture: BM, Middle Bronze, BR, Late Bronze Age; dates: calibrated years) and pollen zones (LPAZ = MT1). The sign '*' marks barren pollen samples

VII No structural evidence.
VIII (1440–1320 B.C.): Granary destroyed by fire, and showing many charred caryopses.
IX No structural evidence.
X (1415–1315 B.C.): No structural evidence.
XI (1415–1315 B.C.): No structural evidence.

Materials and methods

Archaeobotanical sampling

Samples for pollen and macroremains were collected from stratigraphic sequences and occupation levels during the

Table 2 Radiocarbon dates (OxA Oxford University – Radiocarbon Accelerator Unit) from 8 archaeological Phases of the Terramara di Montale[a]

Phases	Lab. code	^{14}C Dates	Calibrated age	
			68.2% Probability	95.4% Probability
I	Oxa – 12415	3282 ± 30 B.P.	1605–1515 B.C.	1690–1460 B.C.
I	Oxa – 12414	3272 ± 31 B.P	1610–1510 B.C.	1680–1440 B.C.
II	Oxa – 12413	3250 ± 30 B.P.	1600–1450 B.C.	1610–1430 B.C.
V	Oxa – 12412	3141 ± 31 B.P.	1490–1320 B.C.	1520–1310 B.C.
VI	Oxa – 12411	3157 ± 29 B.P	1495–1400 B.C.	1520–1320 B.C.
VIII	Oxa – 12564	3130 ± 30 B.P.	1440–1320 B.C.	1500–1310 B.C.
X	Oxa – 12410	3086 ± 28 B.P.	1410–1315 B.C.	1430–1260 B.C.
XI	Oxa – 12409	3103 ± 29 B.P.	1415–1315 B.C.	1440–1260 B.C.

[a]Calibration with OxCal 3.9

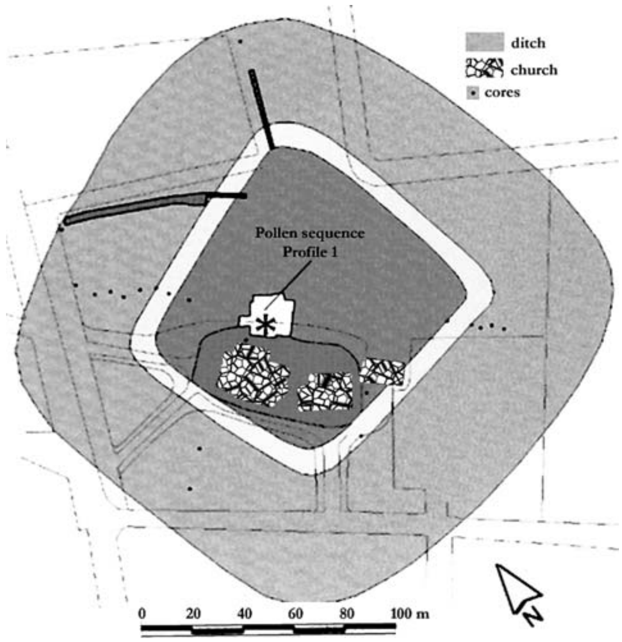


Fig. 4 Sampling location of the pollen sequence – Profile I within the area excavated in the years 1996–2002: this area, white in the figure, is near a church and the streets of the small centre of Montale. Several exploratory cores intercepted the embankment and the ditch which surrounded the Terramara

excavations in 1996–2001. No samples were examined from Phase XI as this had been affected by depositional disturbance. Plant names, habitus and ecology follow the Flora d'Italia (Pignatti 1982).

Three vertical profiles plus some scattered samples were collected for pollen analyses. Only Profile I, taken on-site in 1996 (Figs. 3 and 4), has been studied so far. Its stratigraphy shows all of the main units described above:

(a) 350–300 cm: palaeosol;
(b) Archaeological deposits from the Bronze Age (300–280 cm: Unit 1; 279–190 cm: Unit 2; 189–130 cm: Unit 3; 129–35 cm: Unit 4);
(c) 35–0 cm: Layer 1, modern age, commences at 25 cm depth, i.e. 0 cm = top of Layer 1 at 25 cm (Cremaschi 1997);
(d) Recent material (25 cm) covers the series.

43 samples were collected in the field from the exposed Profile 1, from 325 to 0 cm depth, at 3–12 cm intervals, taking into account both stratigraphy and archaeological phases (Fig. 3). Samples were dried at room temperature protected from contamination.

Sub-samples of about 5–10 g were treated according to Lowe et al. (1996). *Lycopodium* tablets were added to calculate pollen concentration (pollen grains per gram = p/g). Eight samples, in addition to that from Phase XI, showed very few and badly preserved pollen: the upper three from Layer 1 of modern age, plus five others scattered through the Bronze age units (* on Fig. 3).

Identification was made at 1000 × magnification, with the help of keys, atlases and a reference pollen collection. Cerealia pollen identification was based on Andersen (1979), Beug (1964), Faegri and Iversen (1989, with a correction factor for glycerol jelly) and Kohler and Lang (1979).

Pollen brought to the site by human (including animal) activities strongly influences the pollen diagram. Therefore two diagrams are presented: in Fig. 5 the pollen sum excludes Cerealia and Cichorioideae, the most overrepresented anthropogenic taxa while in Fig. 6 the pollen sum also excludes all the other anthropogenic taxa plus aquatics.

The second diagram should reduce the influence of both pollen derived from human activities and pollen produced by plants growing locally near the ditch. In both diagrams the excluded pollen taxa and Pteridophyta spores were calculated as a percentage of the pollen sum plus themselves. Pollen diagrams were drawn with Tilia (Grimm 1991) and TGView. Visual examination of the diagram and CONISS were used for zonation.

A total of 1109 carpological samples were collected from the different phases (40 to 270 per phase) and structures on-site (mainly floors, fire layers, hearths and pits) by systematic grid-sampling. The samples (between 10 and 16 l – average 14 l) comprised a total of 16,000 l of excavated material. The samples were floated and sieved using 0.5 and 0.2 mm meshes in the field by archaeologists. The total residues were sorted under a stereomicroscope in the laboratory. Identification was made at 6 to 80 × magnification with the help of keys, atlases (e.g. Anderberg 1994; Beijerinck 1947; Berggren 1969; 1981; Buxó i Capdevila et al. 1997; Dálnoki and Jacomet 2002; Hubbard 1992; Jacomet et al. 1989; Jacquat 1988; Kreuz and Boenke 2002; Kroll 1992; Küster 1992; Maier 1996; Renfrew 1973; Schoch et al. 1988; Zohary and Hopf 1994) and the reference carpological collection.

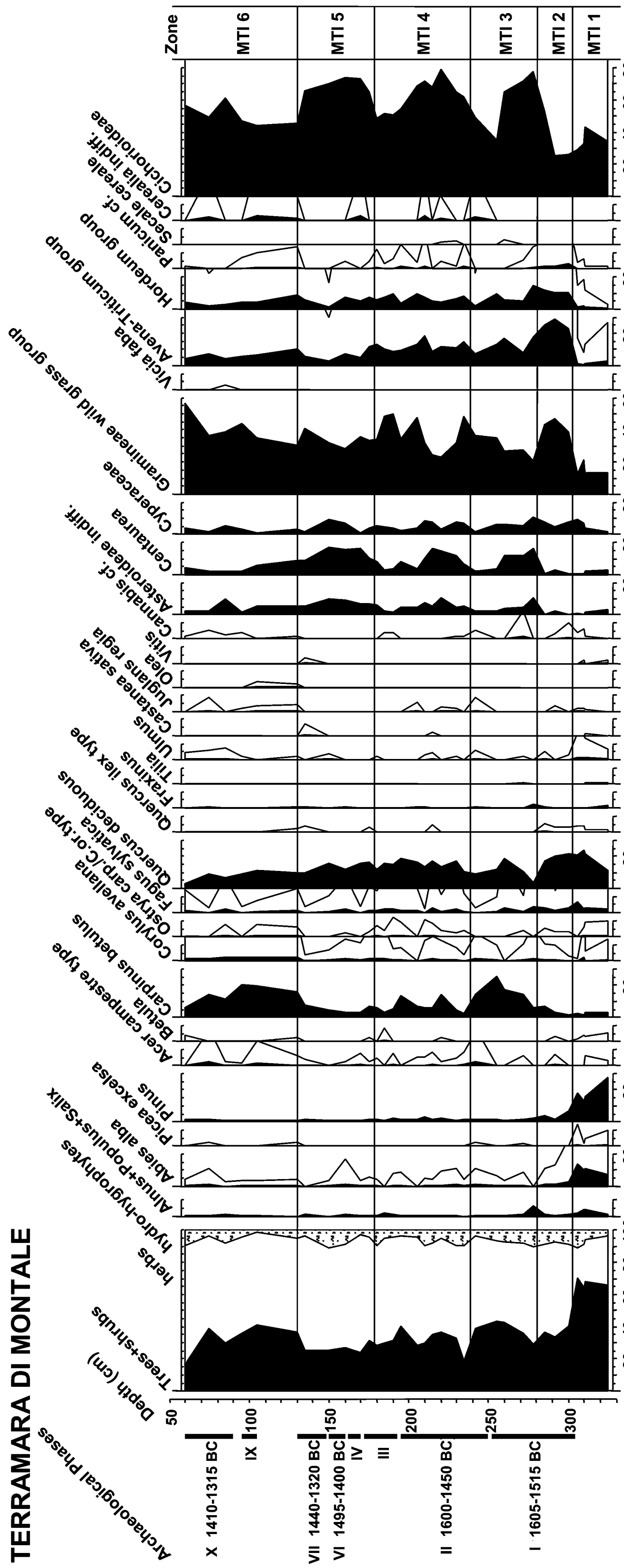
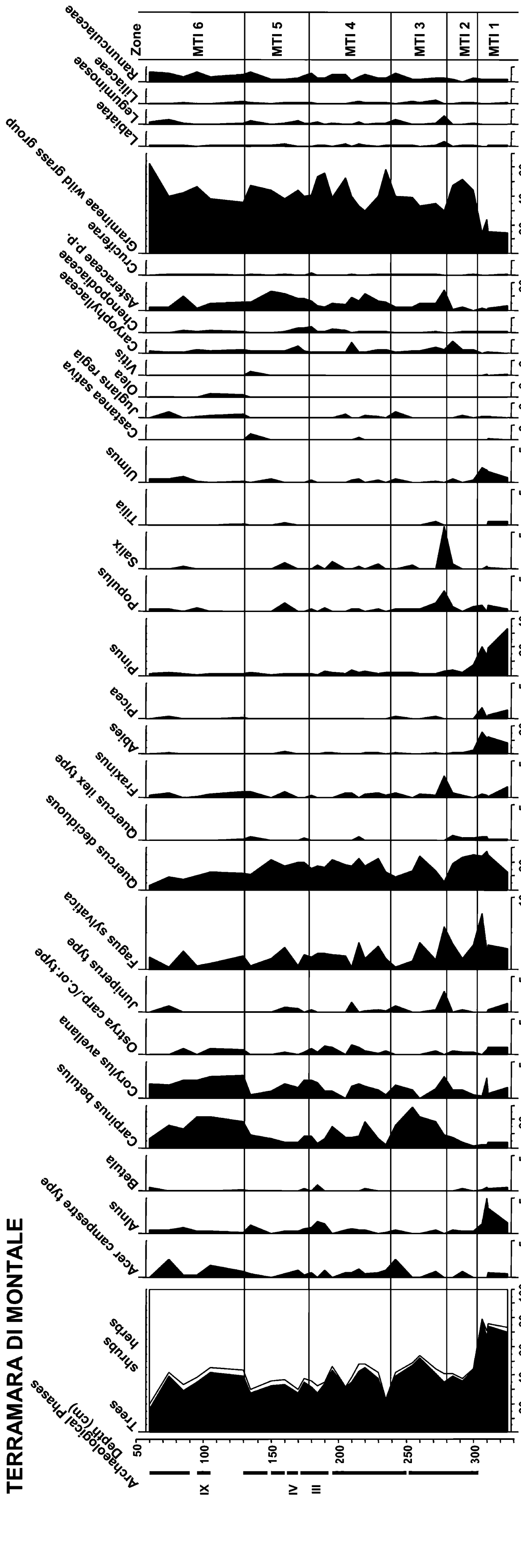


Fig. 5 Percentage Pollen Diagram for Profile 1 (1996 excavation) – depth scale and selected taxa. Pollen sum excludes cereals and Cichorioideae, exaggeration 10 ×



For charcoal and mineralised wood, two kinds of sampling were carried out:

1. Systematic *in situ* hand picked finds during the excavation, with regard to structural elements, tools and the discharging of hearths;
2. Sieving/flotation (see Seeds/fruits-section). – A first study concentrated on a selection of the hand picked finds, mainly to obtain valuable cultural information (i.e. fuel choice, building material and tools) for setting up the Archaeological Park.

The pieces examined included both charcoal and mineralised wood remains.

Charcoal: 389 pieces: 350 from hearth structures, with a size of about 0.5–3.0 cm and 39 fragments of wall/roof elements with a size of about 1.0–5.0 cm. In addition, one sample from a trunk (about 5.0 cm) was taken.

Mineralised Wood: 128 pieces: subsamples of about 0.5–5.0 cm were taken from large to middle sized pieces (20–300 cm): 10 came from tools (3 – bows, 1 – plough, 1 – handle of a chopper, 5 – tools of uncertain purpose) and 118 from structural elements (house piles, fragments of wall esp. roof elements). They were identified using a reflected light microscope to examine cross, tangential and radial sections along fresh hand-made fractures. Identification was based on the anthraco-xylological reference collection as well as on keys and atlases (e.g. Cambini 1967; Greguss 1955; 1959; Grosser 1977; Hather 2000; Jacquiot et al. 1973; Schweingruber 1990).

Results

In total 34 pollen samples (about 970 grains per sample), 78,358 seeds/fruits (98% cereals) and 498 wood/charcoal fragments were examined.

Pollen

In general pollen concentration was not high, ranging from 10^3 to 10^4 grains/g in about 80% of samples. Only in two samples from Phase II, very rich in organic matter, concentration was 10^5 grains/g, reflecting accumulation of straw and fodder. One sample (Phase II) was excluded from the pollen diagrams because of the overrepresentation of *Carpinus betulus* (84%).

All pollen types were recorded with different degrees of preservation, from good to bad, in the same sample. Deterioration mainly consisted in folding of the grains and degradation with various degrees of thinning of the exines. Selective corrosion was not observed even if some more resistant and always recognisable pollen such as Cichorioideae and *Centaurea* might be overrepresented. In fact the high presence of Cichorioideae in badly preserved material from archaeological sites is frequently reported (Bottema 1975; Dimbleby 1985; Horowitz 1992). In Emilia Romagna, other than at Montale, a high proportion of Cichorioideae (up to 77%) was recorded only at the Bronze Age site of Monte Castellaccio – Imola. Here different types of pollen were in a similar and quite good state of preservation, thus excluding selective corrosion (Bandini Mazzanti et al. 1996a). At this site they were interpreted as pasture indicators reflecting animal breeding after Behre (1986), this being confirmed by the straw and coprolites observed in the thin soil sections (Mercuri et al. 1999). Therefore we can conclude that at the Terramara di Montale that Cichorioideae overrepresentation is not due to corrosion but to the deposition of materials of anthropic and animal dung origin.

Pollen flora consisted of 194 types (54 trees and shrubs and 140 herbs). Pollen spectra were dominated by deciduous *Quercus* (mean 14%) and *Carpinus betulus* (mean 9%) among the trees, and by Gramineae – wild grass group (mean 34%) and Cichorioideae (mean 55%) among the herbs.

Four cereal pollen types were found:

(a) the *Avena*/*Triticum* group was the most abundant (mean 10%, prevalent in all phases). It includes most wheats (*Triticum* spp.), the cultivated oat (*Avena sativa*) plus a few wild grasses. In the samples we observed that the well-preserved grains which could be certainly identified belonged prevalently to *Triticum* as defined by Beug (1964; see also below);
(b) the *Hordeum* group (6%), which includes barley (*H. vulgare*), einkorn (*Triticum monococcum*) plus some wild grasses;
(c) cf. *Panicum* (low values), which includes common millet (*P. miliaceum*) plus wild grasses;
(d) Secale cereale (rare).

Six local pollen zones (MTI: MT – Montale, I – Profile I; 33 samples) are distinguished from the base to the top (Fig. 5):

MTI 1 (*4 samples*, *325–305 cm – below Archaeological Phase I*) – Woody plants are relatively high (mean 67.0%; 15,300 grains/g) with conifers at their maximum (*Pinus* 20%, plus low *Abies* and *Picea*) and deciduous trees well represented (*Quercus* 20%, plus low *Fagus*, *Betula*, *Carpinus betulus*, *Ulmus* and *Corylus*). *Alnus*, *Populus* and *Salix* are present. Cereals (3.2%) and abundant Cichorioideae are recorded.

MTI 2 (*3 samples*, *304–281 cm – Archaeological Phase I*) – Woody plants, mainly conifers, suddenly decrease

◀ **Fig. 6** Percentage pollen diagram for Profile 1 (1996 excavation) – depth scale and selected taxa; for chronology see Fig. 5. Pollen sum excludes anthropogenic indicators (i.e. besides cereals and Cichorioideae, *Centaurea nigra* type, *C. cyanus*, *C.* undiff., *Plantago lanceolata* type, *P. media*/*major*, *P.* undiff., cf. *Agrostemma*, cf. *Arctium lappa*, *Artemisia*, cf. *Cannabis*, *Convolvulus*, *Mercurialis*, *Papaver rhoeas* type, *Polygonum aviculare* type, *Rumex*, *Urtica dioica* type, *Vicia faba*) and aquatics (i.e. *Alisma plantago-aquatica*, *Butomus*, Cyperaceae, *Hydrocharis*, *Juncus*, *Lemna*, *Menyanthes* *Myriophyllum*, cf. *Nymphaea alba*, cf. *Phragmites australis*, *Potamogeton*, *Sagittaria*, *Sparganium erectum* type, *Typha latifolia* type) (mean 36.7%; 10,200 grains/g). There is also a decrease in *Alnus* alongside an increase of hydro-hygrophytes. Deciduous *Quercus*, the most abundant taxon (20%), decreases at the top of the zone, most probably cut to build the houses and *Carpinus betulus* begins to increase. Cereals (39.1%) and wild Gramineae also increase notably. These changes clearly characterise the establishment of the settlement.

MTI 3 (*5 samples*, *280–239 cm – Archaeological Phases I–II*) – There is some increase in tree pollen (mean 37.8%; 23,100 grains/g), mainly due to *Carpinus*. *Fagus* decreases and *Betula* disappears for a while. Wetland pollen is quite steady. Cichorioideae show a net gain while cereals (21.4%) decrease.

MTI 4 (*10 samples*, *238–179 cm – Archaeological Phases II–III*) – Forest pollen is fairly steady although it decreases slightly in mean percentage (mean 31.3%; 34,300 grains/g); *Carpinus* fluctuates. Cereals are also fairly steady (20.3%). At first there is a decrease and then an increase in Gramineae alternating with *Centaurea*, other Asteroideae and Cichorioideae.

MTI 5 (*5 samples*, *178–131 cm – Archaeological Phases III–VII*) – There is a decrease in forest pollen (mean 26.8%; 10,500 grains/g). *Quercus* and cereals, mainly the *Avena*/*Triticum* group, are also decreasing.

MTI 6 (*6 samples*, *130–60 cm – Archaeological Phases VIII–X*) – There is a revival in forest pollen, then a decrease at the top of the zone (mean 33.0%; 9800 grains/g), mainly following the curve of *Carpinus*. There is a slowly decreasing trend in *Quercus* and cereals. *Centaurea* and Cichorioideae also decrease.

Throughout the diagram, the *Avena*/*Triticum* and *Hordeum* groups show similar trends: they are low prior to the Terramara, increase notably at its onset, remain fairly constant for a while and then decrease towards the top (Fig. 4). However, their ratio changes:

(a) in MTI1, below Archaeological Phase I, they show similar proportions (*Avena*/*Triticum* 1.6%, and *Hordeum* 1.2%);
(b) in MTI 2–4, Phases I–III, the percentage of the *Avena*/*Triticum* group is more or less double that of the *Hordeum* group (means for these zones: *Avena*/*Triticum* 14.5%, and *Hordeum* 7.6%). In these zones some large pollen grains (diameter 60–70 μm, porus + annulus 15–17 μm large and >2.5 μm thick) are certainly from hexaploid wheat, e.g. *T. aestivum*;
(c) in MTI 5 and MTI 6, Phases III–X, the ratio of the cereal types returns to ca.1 as in MTI 1 (means for these zones: *Avena*/*Triticum* 6.5%, and *Hordeum* 5.0%).

Seeds and fruits

Seeds and fruits were found in all phases (I–X) at concentrations of ca. 10 to 1000 per 10 l.

The state of preservation of the remains was generally bad. Three types of preservation were observed:

1. charred (or partially charred), sometimes fragmented or deformed (also puffed cereals in the granary – Phase VIII), frequently unidentifiable;
2. waterlogged ('mainly uncharred' in Table 3); seeds/fruits with a very lignified coat seem to dominate in this record, even though some records of less resistant taxa such as Pomoideae were found. This suggests that selective preservation of the subfossils occurred;
3. mineralised, with only the shape preserved, not certainly identifiable.

In Table 3, these records are mainly included in "Other herbs" and in the Boraginaceae. The preliminary mineralogical analyses, still in progress on mineralised records with a shape resembling cf. *Valerianella dentata*, suggest that a process of phosphatisation possibly occurred (Vezzalini, pers. comm.). It is well known that mineralised remains are the result of phosphatisation (Carruthers 2000; Jacomet 2003), typical of organic-rich deposits such as human faecal deposits and dung (McCobb et al. 2003). The latter may be the case in the deposit from the Terramara.

The carpological flora consists of 41 taxa (Table 3), composed of 19 woody and 22 herbaceous taxa. Cultivated plants, mainly cereals and a few legumes, are dominant. With one exception – the granary in phase VIII – the remains represent mainly thanatocenoses mixed with some natural and occasional inclusions.

Cereals, all charred, make up 98% of the records and were prevalent in all phases (Table 3). Most of the finds were carbonised grains. About 70% were indeterminable. The identifiable grains belonged mainly to *Triticum dicoccum, T. aestivum*/*durum* together with some *T. monococcum* (also revealed by a few chaff remains, a total of only a dozen from all the samples together), *Hordeum vulgare* (hulled forms) and few *Panicum miliaceum*, *Avena* sp. and *Secale cereale*.

Charcoal and mineralised wood

The charcoal analysed comes from Phases I to V, the mineralised wood from Phases II to VI (Table 4).

Generally, charcoal was well preserved. Physical and chemical alterations that take place during charring change as a function of time, temperature and the chemical composition of the heated plant remains (Poole et al. 2002; Braadbaart et al. 2004, Braadbaart and van Bergen 2005). Thus at Montale, in the same layers, charcoal was found in a better state of preservation than the carbonised seeds and fruits.

Uncarbonised wood was present in the settlement phases, above Phase I, with a different degree of mineralisation.

The anthraco-xylological flora includes 24 types (Table 4). All of them are regional wild trees/shrubs. Deciduous oaks dominate (55%).

Charcoal (390 records): *Quercus* (*Q*. deciduous, *Q*. sect. *robur*, and *Q*. sect. *cerris*) is dominant, accompanied by several other taxa such as *Carpinus*, *Corylus*, *Fagus* and *Acer* (Table 4). In Phase I, one trunk of *Q*. sect. *robur*, marking the base of the Terramara, was also found (Fig. 2a). In

Table 3 Seeds and fruits recorded per archaeological phase: state of preservation, total number, concentration per 10 l, percentage of total cereals and all other records[a]

Phases		I	II	III	IV	V	VI	VII	VIII	IX	X	Total
No. of samples		110	271	223	39	65	60	127	88	85	41	1109
Vol. (l)		2210	4750	3790	690	670	590	1230	840	910	320	16000
Cereals												
Hordeum vulgare	Charred	101	260	452	142	204	380	652	5137	87	33	7448
Triticum spp	Charred	235	579	2084	327	515	361	659	11566	378	121	16825
% *T. aestivum/durum*		*32*	*44*	*44*	*57*	*54*	*61*	*47*	*46*	*55*	*67*	*48*
% *T. dicoccum*		*67*	*50*	*37*	*34*	*42*	*38*	*52*	*53*	*43*	*31*	*43*
% *T. monococcum*		*1*	*5*	*19*	*9*	*3*	*2*	*1*	*1*	*2*	*2*	*9*
Other cereals (*Secale cereale*, *Panicum miliaceum*, *Avena* sp.)	Charred	10	31	23	2	19	17	14	23	2	6	147
Cereals, indet	Charred	531	1224	3060	388	1266	1650	1600	40821	1614	273	52427
Cereals sum		877	2094	5619	859	2004	2408	2925	57547	2081	433	76847
Other records												
Gramineae-wild grass	Charred	1	11	12	4	9	2	8	68	1	1	117
Vitis vinifera	Mainly uncharred		1	5	4	2		5	27	92	74	210
Cornus mas	Mainly uncharred	87	34	101	2	6	16	36	91	8	6	387
Pomoideae, Prunoideae, *Rubus fruticosus* s.l	Uncharred	2	9	11	2	1		2	7	2	1	37
Quercus sp	Uncharred/charred	7	42	15	3	11	4	8		1		91
Corylus avellana	Uncharred	1	3			1						5
Carpinus betulus cf	Uncharred			3				2				5
Rhamnus cf	Uncharred		1									1
Vicia faba	Charred	10	10	15	2		4	4		2	1	48
Other Fabaceae (*Vicia* sp., *Lens culinaris*, indiff.)	Charred	8	8	16	4	6		3	6		3	54
Boraginaceae	Uncharred/mineralised		5	12	1	1	2	1	127	1	1	151
Sambucus ebulus/nigra	Uncharred/charred	2	14	2		11	2		20	1	22	74
Other herbs	Mineralised/uncharred	9	10	8	1	3	2	3	49	4	30	119
Other records sum		*127*	*148*	*200*	*23*	*51*	*32*	*72*	*395*	*112*	*139*	1299
Indet	Charred/ uncharred	*9*	*25*	*16*	*2*	*15*	*6*	*7*	*85*	*18*	*29*	212
Total records		1013	2267	5835	884	2070	2446	3004	58027	2211	601	78358
Total concentration (10 l)		5	5	15	13	31	41	24	691	24	19	
% cereals		87	93	97	97	97	99	98	99	95	76	98
% other records		13	7	3	3	3	1	2	1	5	24	2

[a]In this overall table several taxa are incorporated, but not listed, in either Pomoideae (*Malus sylvestris*, *Pyrus pyraster*, *Sorbus domestica*, *Sorbus* sp.), Prunoideae (*Prunus spinosa*, *P. avium*, *P. domestica* subps. *insititia*), Boraginaceae (*Buglossoides arvensis*, *Lithospermum officinale*, *Echium vulgare*) or 'other herbs' (*Rumex acetosella*, *R. sanguineus/conglomeratus*, *Carex* sp., *Fumaria officinalis*, *Galium* sp., cf. *Geranium pratense*, *Mentha suaveolens/longifolia*, *Portulaca oleracea*, *Valerianella dentata*, *Verbena officinalis*, etc.)

Table 4 Anthracological and xylological records per phase[a]

Phases	I		II				III				IV	V			VI		Total
Kind of record	hc	tr	p	bt	s	t	p	bt	s	t	s	hc	s	t	s	t	
Anthracological records																	
Acer	33										1	1					35
Alnus	24																24
Alnus cf. *glutinosa*				1													1
Carpinus	52			1	3												56
Carpinus/*Corylus*	1												1				2
Castanea	1																1
Corylus	10																10
cf. *Crataegus*	1																1
Fagus sylvatica	22								1								24
Frangula alnus	1																1
Fraxinus	4											1					5
Fraxinus cf. *oxycarpa*				1													1
Ostrya carpinifolia	2																2
Platanus	1																1
Populus/*Salix*	27			1					1		1		1				31
Quercus deciduous	79	1		1	4				4			1	2				92
Quercus sect. *cerris*	18																18
Quercus sect. *robur*	66			1	4				3			1	2				77
Salix	2										1		1				4
Ulmus				1					1								2
Indet	2																2
Total Sum	346	1		7	11				10		4	4	7				390
Xylological records																	
Acer					1	2		1								2	6
cf. *Corylus*										1							1
Fraxinus				1													1
Populus/*Salix*			4	1	2	3	2										12
Prunus				1													1
Quercus deciduous			18	1	34		13	1	5		2		4		1		79
Quercus sect. *robur*					2			1		1	3			1			8
Rosaceae				2	1												3
cf. *Tilia*				1													1
Ulmus							1										1
Vitis vinifera				1				1									2
Indet			8	1	1		2		1								13
Total Sum			30	9	41	5	18	4	6	2	5		4	1	1	2	128

[a]Type of record: hc, discharged hearth charcoal, tr, trunk; p, house piles inc. fragments of structural elements supporting framework and roof, bt, branches, twigs, structural elements of walls, s, fragments of other structural elements; t, tool fragments

the other Phases (II–V) there were mainly structural elements, mostly of *Quercus*, plus few made of *Populus/Salix*, *Ulmus* or *Alnus*.

Mineralised Wood (128 records): Most of the house piles were made of *Quercus*, plus some *Populus/Salix* and *Ulmus* while the wall frames are of *Fraxinus* and the bundles of twigs between the frames are of *Populus/Salix*, *Prunus spinosa*, other Rosaceae, deciduous *Quercus*, *Tilia* and *Vitis vinifera*. The tools were made of *Acer*, *Populus/Salix*, and again *Quercus*.

Discussion

Montale and the plant landscape in Emilia Romagna during the Subboreal

The pollen diagram from the Terramara di Montale reflects the typical characteristics of the Subboreal of the Emilia Romagna plain (Accorsi et al. 1999), with deciduous *Quercus* and *Carpinus betulus* prevailing in the mixed oak forest (*Querco-Carpinetum*, Pignatti 1953; 1998).

Off-site/on-site pollen diagrams

In the region the mixed oak forest spread from the Boreal onwards. In the Subboreal off-site diagrams (ca. 5800–2700 cal B.P.) it dominates the pollen spectra. A mean value of 65% was calculated for spectra from nine sites (Accorsi et al. 1999). Therefore it is not surprising that at Montale, at the base of the archaeological sequence, the arboreal pollen sum was similar to off-site diagrams from the region (67% – Fig. 4; 72% – Fig. 5).

In contrast, the sum of the mixed oak woodland was generally lower, around 15–35% (pollen sums = total pollen) in the on-site pollen spectra from several Bronze Age sites (e.g., Terramara di S. Rosa di Poviglio: Ravazzi et al. 1992; Monte Castellaccio: Bandini Mazzanti et al. 1996b; Tabina di Magreta: Bertolani Marchetti et al. 1988). This is also the case in the Bronze Age settlement layers of Terramara di Montale (27–37%; Fig. 4). The sum also remains low when all anthropogenic indicators and locally growing aquatics are excluded from the pollen sum (31–43%; Fig. 5). Therefore the onset of the Terramara is not only visible in the archaeological record but also in the pollen record at the transition from MT1 1 (paleosol) to MT1 2 (onset of the Terramara).

Plant landscape and human influence around the site

The landscape around the Terramara di Montale as suggested by the pollen spectra is characterised by a patchwork of forested and open areas during the Subboreal. On the plain, the mixed oak wood included *Quercus robur* L. s. str., sometimes identified among the deciduous *Quercus* even at Montale (by comparison with reference slides) and *Carpinus betulus*, together with *Ulmus*, *Ostrya carpinifolia/C. orientalis* type, *Acer campestre* type, *Fraxinus excelsior* type, *F. ornus* and *Tilia*.

Ulmus and *Tilia* show the typical relationships observed in the Subboreal, i.e. that *Ulmus* prevails over *Tilia* with an inversion as compared to the Atlantic (*Ulmus* from 2 to 5% and *Tilia* from 6 to 2%, from the Atlantic to the Subboreal, mean data from 35 sites on the plain; Accorsi et al. 1999). This was possibly due to competition or local ecological changes, or even overexploitation of *Tilia* for leaf fodder (Lowe et al. 1994; Accorsi et al. 1999). Conifers (especially *Pinus* and *Abies*) that had been previously more abundant, were more and more replaced by the mixed oak wood in the plain, and by *Fagus* in the hills and mountains. This is particularly evident for *Abies* the values for which decreased at the transition from the Atlantic to the Subboreal. Human impact cannot be excluded as a reason since this tree has always been used as timber; however no clear evidence of this had been recorded in the region until now. Wood or charcoal that would certainly indicate an anthropic use of *Abies* is missing from the sites preceding the Roman age examined so far (Accorsi et al. 1989, 1998b). In nearby Tuscany, significant declines in the percentages of *Abies* and *Quercus* pollen at Lago Padule (Tusco-Appennines; Early Holocene) that were associated with an increase in *Corylus* were considered equivocal signals indicating either the influence of Mesolithic people or varying competition between these plants (Lowe et al. 1994).

The Terramara di Montale and the use of wood

The inhabitants of the Terramara collected timber mainly from local mixed oak woods (deciduous *Quercus*, *Acer*, *Fraxinus*, *Tilia*, *Ulmus*, *Carpinus betulus*) and river woods (*Populus/Salix*, *Alnus*). *Fagus* and *Castanea*, found in the charcoal remains, grow at present in the hills and mountains and no longer occur wild in the Po Plain.

As regards piles, *Quercus* seems to have been the most favoured wood at Montale (Forlani 1988 and data in this paper). In fact oak was also chosen in the Bronze Age settlements of Palafitta di Parma (Avetta 1909), Castione Marchesi (Rottoli 1988, 1997a; Nisbet and Rottoli 1997) and S. Ambrogio (Forlani 1988). As to tools, at Montale *Acer* was used for bows, *Populus/Salix* for a bow and a spatula and *Quercus* for a plough and a chopper handle.

In general, people appeared to have a good knowledge of the technological qualities of woods as has been already reported from other Bronze Age sites in Italy (Acanfora 1970; Follieri 1970, 1974; Marzatico 1988; Perini 1988). Thus they mainly used oak, a hard and very resistant wood, for piles supporting framework and roofs, while for walls less hard wood was used and, for tools wood best fitted for the making of the objects was chosen.

Cereal cultivation around the site

One of the most striking features of the archaeobotanical record from the Terramara di Montale is the large presence of cereals as pollen and carbonised grains. Together they point to the presence of cereal growing immediately around the site.

Cereal fields from pollen evidence

It is well known that cereal pollen is not easily transported a long distance from source by wind. Because of the low production and limited dispersal it is not commonly found far from the fields of origin (Bottema 1992). The mere presence is likely to reflect local cultivation (Dark 2005). In archaeological contexts high values of such pollen indicate that flowering spikes or mature spikes with pollen trapped within the glumes, or pollen trapped on cereal collectors were brought to the site by people (Robinson and Hubbard 1977; Bottema 1992). To determine the distance from which the transport of cereal pollen within spikes had occurred in the Terramara di Montale we can link pollen with archaeological evidence. As already reported, more than 220 sites have been discovered by archaeologists in the Po Plain giving rise to the estimation that one site per 9–10 km, and sometimes per 2–3 km, would have been occupied at the same time during the Middle and Late Bronze Age (Cremaschi 1997). Each site had an area of influence, depending on the size of the settlement, its distance from other contemporary sites and the chronological phase, that was exploited for subsistence resources (Cardarelli 1988). For example, during BM2 (central period of the Middle Bronze Age), in the south-western plain of Modena, ten sites were settled including Montale. Montale was ca. 4 km from the little settlement of Gazzate to the east and ca. 2 km from the little settlement of Cà del Vento to the west. During the central phase of BM2, all the sites were about 1.8 km apart (this was on average the radius of one settlement plus its territory), and each of them had an area of influence of up to 4.5 km that could have provided resources (Cardarelli 1997). This is the area of land that would have been exploited by the people of Montale, with the fields nearer the settlement on good soils that were not exposed to flooding (Bernabó Brea et al. 1997).

Cereal-based economy by macroremains

Most of the cereal taxa recorded at Montale (mainly *Triticum* and *Hordeum*, see above) are frequent in the deposits of the Bronze Age of the region, with the exception of *Secale cereale*, only found at the Monte Castellaccio village (Middle Bronze Age; Bandini Mazzanti et al. 1996b). Macroremains of *Panicum miliaceum* have been recorded in Northern Italy since the 2nd millennium B.C. at Canàr (Early Bronze Age; Castiglioni et al. 1998; Castelletti et al. 2001). The lack of spelt is remarkable (*Triticum spelta*). This is in strong contrast with the alpine fringes in Northern Italy where in Bronze Age settlements like Fiavé (Jones and Rowley-Conwy 1984) spelt is very frequent (the same holds for northern Alpine lake dwellings; Jacomet et al. 1998). In the archaeological sites on the Po Plain, in particular those located in the central south-eastern Po Plain (e.g. Castellaro del Vhó, S. Ambrogio, Monte Castellaccio, Canàr; Rottoli 1997b; Forlani 1988; Bandini Mazzanti et al. 1996b; Accorsi et al. 1998a) spelt is rare or even absent. Here, as in Montale, the main hulled wheat was *T. dicoccum*. In later periods, *T. spelta* remained unimportant in the economy of Emilia Romagna. The reason is still under investigation, but probably it has to do with the fertility of the plain that favoured the spread of *Triticum aestivum/durum*. According to Nesbitt and Samuel (1996), it seems that the shift from emmer to spelt which occurred in central Europe during the Bronze Age was possibly part of an expansion of agriculture onto poorer soils. In general, the Po Plain is still today a highly fertile land largely devoted to agriculture. Only in the more recent phases (BM3b-BR1; Figs. 3–5), does it seem that there was a crisis due to overexploitation around the Terramara which made the soil locally poorer for some years (see below). Probably this was not sufficient to open the way for a major introduction of spelt in the plain.

The interpretation of the carpological record

The large quantity of cereal grains is in accordance with the availability of cereals in the area, but it can be stressed that the carpological record is not unquestionably typical of a ‘producer’ site. In fact, traditional crop processing models establish that in a cereal ‘producer’ site all stages of crop processing should be present and that especially the early stages are carried out by the primary producers (e.g. van der Veen 1995; Ibáñez Estévez et al. 2000). Thus, in a carpological record such stages can be read by identifying and comparing the proportions of different crop plant components, including cereal chaff (rachises, glumes, paleas, lemmas) and culm nodes from straw which were related to waste products of the various stages of crop processing and also by seeds/fruits of weeds which grow in the fields together with cereals (Harvey and Fuller 2005). Such models seem not to be a good interpretative tool in the case of Montale. In fact here cereals consisted almost all of grains that came into contact with fire so that they were preserved by charring. The preservation of waste products and weeds can be different to that of grains and in charred plant assemblages most of them could have been destroyed at different times (Harvey and Fuller 2005). Thus fragile chaff fractions and weed seeds/fruits may not survive because they are burnt away at temperatures too high for their preservation (Boardman and Jones 1990). Furthermore straw waste and other early processing products are unlikely to come into contact with fire and thus are not preserved by charring (Jones 1987). This modifies the proportion of each fraction making it difficult to recognise the early stages of crop processing, thus affecting the interpretation of the carpological data alone as to the classical question of distinguishing between ‘producer’ and ‘consumer’ sites (Harvey and Fuller 2005).

At Montale, it is highly probable that a loss of material, especially chaff and weeds, occurred during subsequent fire episodes (Phases II, III and VIII) and thus not all stages of cereal processing were preserved on site. Moreover, it must be recalled that our data refer to a limited area within the Terramara which was devoted to built huts or a granary in the different phases, while some activities such as threshing and winnowing after harvest were probably carried out in more open parts of the settlement.

We can conclude that the large amount of charred cereal grains can be interpreted as representing the fields in the area of influence of the Terramara.

Legumes

In the Terramara di Montale, legumes were found in much lower quantities than cereals (<0.1% of seeds/fruits – Table 3; traces of *Vicia faba* pollen in MTI 6). The few seeds include *Vicia faba* var. *minor*, plus a few *Vicia* spp. and *Lens culinaris*. These are the same species as at other sites in the region, sometimes joined by *Pisum sativum* and *Vicia ervilia* (Bandini Mazzanti and Taroni 1988a; Castelletti et al. 2001).

The sparse presence of legumes has already been observed at other Emilian sites of the Bronze Age (Bandini Mazzanti and Taroni 1988a,b; Bandini Mazzanti et al. 1996b; Nisbet and Rottoli 1997). This is known to be a real characteristic of the Bronze Age deposits from the Po Plain (Castelletti et al. 2001).

Other plants possibly used

Cannabis *growing* (*pollen*) – cf. *Cannabis* was found as traces in all pollen zones (max. 1.7% in one sample from MTI 3) with the exception of MTI 5. This suggests the use of hemp and possibly its cultivation near the ditch. This has already been clearly documented by high pollen percentages (25 and 7%) found in two middle Bronze Age layers from a ditch at the Terramara di Santa Rosa di Poviglio (Ravazzi et al. in press). Similar or even lower values are commonly reported in the literature as reflecting cultivation around the investigated sites (Mercuri et al. 2002 and references therein).

Furthermore scarce pollen records from archaeological sites in northern Italy, including the Bronze Age site Canàr-Rovigo (Veneto; Accorsi et al. 1998a), were regarded as possible indicators of the use and cultivation of hemp in the area based on the whole archaeobotanical-archaeological contexts. In general pollen records showed that hemp grew wild in Italy long before humans realised its use, but its history of cultivation began later (Mercuri et al. 2002). Probably it occurred as a weed before it was cultivated when hemp was introduced with cereals during the Neolithic period (Wick in Mercuri et al. 2002: p. 272). Nevertheless macroremains of hemp are absent from the Bronze Age sites of northern Italy. At the present state of knowledge we can only infer that *Cannabis* was cultivated at Montale through comparison with the pollen records from Santa Rosa di Poviglio.

Wild plants for food or fodder (*seeds/fruits*) – Among the wild plants such taxa prevail as were most probably used by humans, for their own purposes or for foddering livestock. They were collected in the surroundings of the settlement. These were *Cornus mas* (prevalent), *Corylus avellana*, *Malus sylvestris*, *Quercus* sp., *Prunus spinosa*, *Sambucus nigra*, *Sorbus* spp., *Vitis vinifera* and others. *Vitis vinifera* is included in this group as the morphology of the pips did not yield unambiguous proof of cultivation or pre-cultivation.

Vitis *and* Cornus *for drinking (seeds/fruits)* – Cornelian cherry stones are always more abundant than grape pips, except in the two top phases IX and X, where grape pips dominate (Table 3). Based on the similarly good state of preservation of the two types and the total absence of variable degrees of degradation, we can exclude the possibility that in this case a bias due to a selective preservation of Cornelian endocarps and vine pips occurred. As both fruits are used to prepare fermented drinks, the inversion could suggest a cultural shift in alcoholic drinks from cornelian cherry wine to grape wine, as already suggested by Castelletti et al. (2001) for northern Italy at the transition from Bronze Age to Iron Age.

Carpinus betulus *for fuel and fodder (macroremains and pollen)* – *Carpinus betulus* nuts were found in phases II and III, where the pollen was also abundant. Either these fell by chance from hornbeam trees growing among the houses (but in the xylo-anthracological samples, trunks and roots have not been recorded so far) or the pollen was wind transported or both were from branches collected as fuel or as fodder. The use as fuel was documented by charcoal finds. The use as fodder was suggested by the pollen sample with the overrepresentation of *Carpinus* (Phase II). In fact, this sample had features which if present together in the same sample, could be regarded as indicative of input of dung from herbivorous mammals to the sediment (Mead et al. 1987; Faegri and Iversen 1989; Trevisan Grandi et al. 1998; Mercuri 1999; Hunt et al. 2001). These are the dominance of one pollen type, also mostly occurring in clumps, a variable state of preservation of this pollen showing different degrees of exine thinning, the presence of fungal spores and a very high pollen concentration (331,000 grains/g).

Cichorioideae suggesting animal breeding (*pollen*) – The Cichorioideae overrepresentation in the pollen samples mainly reflects the deposition of animal dung at the site. Preliminary data show that ovicaprines were dominant in the archaeozoological record, followed by pigs and few cattle (de Grossi Mazzorin and Ruggini in Cardarelli 2004). This suggests that in the territory of influence of the Terramara di Montale pastures were used for grazing of domestic animals.

The history of the Terramara and the possible role of climate

The history of the Terramara, as shown by plant records within the whole framework of archaeological-archaeoenvironmental evidence, developed in four main steps in which as a general rule (e.g. Kalis et al. 2003), the human-induced effects cannot always be easily separated from natural succession.

Before the Terramara: Before the onset of the Terramara, the landscape was largely natural with a fairly sparse forest growing in the area, although cereal fields and pastures (traces of cereals and abundant Cichorioideae pollen, see above) suggest that human settlements were present in the area. In fact few archaeological records of the Late Neolithic Copper Age were found in the deposits from Montale (below Phase I) but other sites of this age were discovered in the region (Bandini Mazzanti et al. 1996a; Bernabó Brea et al. 1997).

The forest cover consisted of mixed woods with conifers and broad-leaved trees, the latter mainly deciduous *Quercus* and *Carpinus betulus*. Trees requiring cool conditions (*Abies*, *Pinus*, *Picea*, *Fagus* and *Betula*), growing today in mountains and hills, also grew at a lower altitude, along the border line with the plain or on the plain itself (*Fagus*; Accorsi et al. 1999). The hillock where the Terramara was built was surrounded by a river along which grew fresh water plant communities. It was covered by a light deciduous oak forest, as indicated both by the pollen record and the charred trunk of *Quercus* discovered at the base of the stratigraphic series. The presence of the hillock, the light forest, the abundance of water and the natural defensive river barrier offered a site that, even if endangered by floods, was very suitable for settlement.

The onset of the Terramara, around 1600 B.C. (*3550 cal B.P.*): A sudden decrease in trees occurred just before or at the onset of the Terramara. This is marked in the pollen diagrams by the notable change passing from the MTI 1 to the MTI 2 zone, i.e. the decrease in conifers and increase in deciduous oak with the sudden rise in cereals. People cleared the surrounding forest to provide timber and space. They settled mainly in semi-open areas and became in turn major agents in opening the landscape (Accorsi et al. 1999).

In particular, deciduous *Quercus* was cut to build the pile houses. Meanwhile *Carpinus betulus* starts to increase, due to its more rapid growth expanding into spaces previously occupied by oaks. The decrease in *Alnus* alongside an increase in hydro-hygrophytes could have been produced by the excavation or first enlargement of the ditch from the river. This ensemble of data suggests that human influence increased markedly, however climate could also have been involved. Indeed the decrease in some of the conifers could indicate a warming.

At this point in time, clear climatically and human forced vegetational changes were detected in continental and marine cores from Italy (e.g., at Lago di Mezzano, Ramrath et al. 2000; Sadori et al. 2004; and in core RF95-30, Oldfield et al. 2003). In particular, the marine core RF95-30 showed major changes in vegetation directly related to human activities within the sediment source area, which included the Po Plain and the eastern slopes of the central-northern Apennines. A clear episode of deforestation and agricultural expansion, also indicated by increased terrigeneous sedimentation and changes in the benthic foraminiferae assemblages, began at 3600 cal B.P. It was synchronous with variations in sea-surface temperature that suggested a climate change, namely a trend to desiccation, also started at this time (Oldfield et al. 2003). An increase in 'aridity markers', i.e. *Quercus ilex* type, *Olea*, *Phillyrea*, *Pistacia*, *Artemisia* and Chenopodiaceae, also occurred at Lago di Pergusa (Sicily) and in the Central Adriatic cores PAL94-9 and PAL94-8 (phase 3800–3600 cal B.P.; Sadori and Narcisi 2001; Mercuri et al. 2004; Sadori et al. 2005). In central Italy, deforestation and low lake levels were recorded at Lago di Albano, Lago di Bolsena, Lago di Mezzano and Lago di Vico (phase 3800–3700 cal B.P.; Magri 1999; Giraudi 2000; Sadori et al. 2004; Sadori 2005). Based on microcharcoal analyses which documented the absence of human-induced fires during this phase, Sadori et al. (2004) established that climate primarily forced this deforestation, but after one or two centuries human influence became clearly seen in the area. Evidence for climate-induced changes was also observed at this time in pollen records from the Mediterranean basin, namely an aridification phase (phase 4300–3400 cal B.P. with a peak around 3900–3800 cal B.P.; Jalut et al. 2000, and references therein). Further to the north, Schmidt et al. (2002) observed that alpine land-use ('Almwirtschaft'), closely related to climate, occurred during a warmer period in the late Bronze Age around 3500 cal B.P. Low lake levels were detected at Lake Constance and Lake Nussbaumen during which settlements were built on exposed beaches until 3450 (phase 4250–3450 cal B.P.; Zolitschka et al. 2003). However after this phase, with some overlapping, the mid-European lake levels increased, reflecting cooler and wetter climatic conditions since 3500 cal B.P. (phase 3500–3100 cal B.P.; Magny 2004).

At the onset of the Terramara di Montale, the climate could have changed towards a warmer phase, indicated by the expansion of mesophilous oak woods and an increase in *Quercus ilex* that might also suggest a drier phase. The warm and/or dry climatic phase could have favoured the establishment of a settlement on the hillock.

The Terramara phase: This is marked in the pollen diagrams (MTI 2–5) by pollen curves reflecting a quite steady trend in human activities in a cultural landscape directly/indirectly shaped by the inhabitants of the site. The peaks in *Carpinus* could indicate the cutting of oaks that persisted at some distance from the Terramara in the surrounding forest.

Around the settlement an embankment was built and the ditch filled with water was gradually enlarged. Wet environments were maintained and drained (oscillations in pollen of hydro-hygrophytes) to assist water flow and prevent flooding. The fear of flooding was possibly one factor that led to the supporting of the houses on wooden piles from ca. 1600 to 1400 B.C. (Phases I to IV). Later the houses were built without piles directly on the ground.

For about three hundred years the economy of the Terramara was largely based on cereals (also indicated by the carpological record) and domestic animal breeding. The exploitation of wild plant resources seems to have been low but this cannot be completely reconstructed because of the preservation bias in the macroremains and the low level of taxonomic determination normally allowed by pollen. Fields of *Triticum dicoccum*, *T. aestivum/durum* and *Hordeum vulgare* alternated with areas devoted to grazing. At around 1400 B.C. a shift towards greater exploitation of *Vitis* than *Cornus* suggests new knowledge about wine preparation, possibly from contact with people from the south, maybe of the Mycenaean culture (Cardarelli 2004).

The decline at around 1300 B.C. (*3250 cal B.P.*): By this time, signs of crisis of the Terramara had appeared. These are revealed by the pollen diagram (at the end of MT1 6, the whole zone dated around 1410/1315 B.C.; Figs. 5 and 6); the fall in forest and cereal pollen may be interpreted as a first sign of the crisis in the settlement that would agree with the archaeological data. In fact, this phase corresponds to the BM3b-BR1 (Fig. 3) during which the number of settlements in the area diminished while the remaining sites did not enlarge their settlement boundaries (Cardarelli 1997). Pollen data also show less pastures and an increase in open areas with a more stable record of weeds (e.g., *Centaurea nigra* type, *Cirsium*, *Polygonum aviculare* type, *Plantago lanceolata* type) probably occupying abandoned fields. Such a crisis was possibly due to overexploitation of the woods and soils. The environment was less suitable for cultivation than before and the wood was not able to recover quickly. At Lago di Mezzano, Sadori et al. (2004) observed that the type of land exploitation by Late Bronze Age people was less intense at about 1250 B.C. In marine and lake cores the signs of deforestation continued and led to maxima at around 1100 B.C. (Mercuri et al. 2002; Oldfield et al. 2003). In fact archaeological data show that the Terramara di Montale was abandoned at ca. 1200 B.C. when the Terramara culture ceased quite suddenly everywhere in the Po Plain. Whether this was for anthropic or climatic reasons is still being discussed.

In the Mediterranean basin climate was unstable and less arid (Jalut et al. 2000). Cooler and wetter climatic conditions (phase 1550–1150 B.C.; Magny 2004) possibly spread across Italy but such signals are not clearly defined on the Po Plain. According to Cremaschi (1997), climatic changes cannot be regarded as the only force that determined the sudden decline of the terramares. The relative degree of human influence and climatic factors largely differs on a regional scale, but on the Po Plain both Holocene climatic changes and anthropogenic activities produced distinctive geomorphological effects. Here much of the land was deprived of its original vegetation by fluvial modifications such as flooding and through human activities such as forest clearance and ploughing, this producing intense aerial erosion (Marchetti 2002).

Conclusions

The archaeobotanical investigation shows that the Terramara di Montale was a favourable site to settle during parts of the Middle and Late Bronze Age, because of the availability of timber, water and fertile soils. As suggested elsewhere and as a general rule (Zolitschka et al. 2003; Sadori et al. 2005), there are indications that human settlements were possible because a warm or dry phase occurred and that subsequently human activities may have been triggered or determined by climatic changes. People who settled at Montale had their own cultural knowledge of building, cultivation and breeding. They cleared forest, as occurred at other Bronze Age sites of the region (Accorsi et al. 1999), built houses mainly of oak and made tools from suitable wood.

The set of pollen and carpological data, although a loss of material affected the macroscopic record, show that the inhabitants of the Terramara largely founded their economy on cereals (mainly *Triticum aestivum/durum* and *T. dicoccum* and *Hordeum vulgare*). In addition, they grew some legumes and possibly hemp, as did the people of other Terramaras in the region (Ravazzi et al. in press). Moreover, they probably supplemented their diet with some wild plant resources. However, because of bad preservation (hardly any uncharred remains survived) this latter group is most probably underrepresented.

People allowed their animals to graze and fed them exploiting wild plants, e.g. *Carpinus*.

The impact of the settlement on the environment was intense. In about one hundred years in the Montale area the landscape became a cultural one. It was open, with most of the land devoted to cereal fields and pastures. Wet environments were managed. Remote from the site there was a mixed oak woodland. Later signs of cultural changes in plant use appeared. After about 350 years the Terramara was abandoned. Probably a coincidence of many factors (Bernabó Brea et al. 1997), with the synchronous occurrence of climate deterioration and overexploitation as suggested by the archaeobotanical record of Montale, occurred in the area.

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