Il Quaternario
Italian Journal of Quaternary Sciences
***23**(2Bis), 2010 - Volume Speciale - 373-386*

CORSO PORTA RENO, FERRARA (NORTHERN ITALY): A STUDY IN THE FORMATION PROCESSES OF URBAN DEPOSITS

Mauro Cremaschi[1] & Cristiano Nicosia[1]
[1] Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Via Mangiagalli 34, 20133, Milano, Italy. (mauro.cremaschi@unimi.it; cristiano.nicosia@unimi.it)
Corresponding author: M. Cremaschi <mauro.cremaschi@unimi.it>

ABSTRACT: Cremaschi M. & Nicosia C., *Corso Porta Reno, Ferrara (Northern Italy): a study in the formation processes of urban deposits*. (IT ISSN 0394-3356, 2010)
The city of Ferrara (Emilia Romagna, northern Italy) is located on the left bank of the branch of the medieval channel of the Po River, the "Po of Ferrara". This paper presents the results of the geoarchaeological study of the stratigraphic sequence exposed during excavations in Corso Porta Reno, located at an intermediate position between the palaeo-Po alluvial ridge and the adjacent floodplain. The area, also referred to as the "San Romano complex", was excavated between 1981 and 1984, revealing an exceptionally well-preserved sequence, comprising occupation deposits and structural remains dated between the 8th and the late 13th century AD. Geoarchaeological observations in the field and the micromorphological study of soil thin sections allowed the reconstruction of the natural and anthropic processes involved in the formation of the site stratigraphic sequence. This is characterised by an alternating succession of anthropogenic units (trampled domestic deposits, layers deriving from construction, destruction and/or refurbishing of buildings, materials from decantation within anthropic structures) and of natural alluvial deposits (light-coloured sandy layers often showing cross laminations, linked to a crevasse-splay context active during the human dwelling). The waterlogged nature of the site, the rapid rate of sedimentary accretion, and the sealing of the sequence due to the construction of a brick house in the 13th century avoided the well-stratified deposit to be heavily homogenized by bioturbation or reworked by later human activities. The model envisaged at Corso Porta Reno could partly explain the strong vertical accretion of urban deposits during the Middle age and provide a possible mode of formation for thick "Dark Earth" sequences in medieval cities in active alluvial settings.

RIASSUNTO: Cremaschi M. & Nicosia C., Corso Porta Reno, Ferrara (Italia settentrionale): studio dei processi di formazione di depositi urbani. *(IT ISSN 0394-3356, 2010)*
L'articolo presenta i risultati dello studio geoarcheologico della sequenza stratigrafica esposta durante gli scavi archeologici in Corso Porta Reno a Ferrara, in un'area posta tra il dosso del paleo-Po e la piana alluvionale adiacente. Il sito, conosciuto anche come "complesso di San Romano", fu scavato tra il 1981 e il 1984 e restituì depositi d'abitato ed elementi strutturali datati tra l'VIII ed il XIII secolo d. C., in eccezionali condizioni di conservazione. Lo studio geoarcheologico sul campo, integrato da quello di sezioni sottili, ha permesso di ricostruire i processi naturali e le attività antropiche responsabili per la formazione della sequenza stratigrafica del sito. Essa è caratterizzata dall'alternanza di unità antropogeniche (depositi di origine domestica soggetti a calpestio, unità derivanti dalla costruzione e/o dalla distruzione di edifici, sedimenti decantati all'interno di strutture negative) e di depositi alluvionali naturali (strati sabbiosi di colore chiaro, spesso con laminazioni incrociate, legati ad un ambiente di lobo di rotta attivo durante la frequentazione antropica del sito).
Le condizioni di saturazione idrica, il rapido accrescimento sedimentario e la costruzione di un edificio in mattoni nel XIII secolo hanno evitato che la stratificazione originaria del sito venisse omogeneizzata dalla bioturbazione o sconvolta da attività antropiche nei secoli successivi. Il modello delineato in Corso Porta Reno potrebbe in parte spiegare la forte crescita verticale delle stratificazioni urbane durane il Medioevo e fornire un modello per la formazione di spesse "Terre Nere" in città poste in ambienti alluvionali attivi.

Keywords: Ferrara; Po river; urban archaeology; "Dark Earths".

Parole chiave: Ferrara; fiume Po; archeologia urbana; "Terre Nere".

1. INTRODUCTION

This paper reports the geoarchaeological study of a stratigraphic sequence exposed in Corso Porta Reno in Ferrara (Emilia-Romagna region, northern Italy) – (Fig. 1). At this site, also referred to as the "San Romano complex", archaeological excavations were carried out between 1981 and 1984 (GADD & WARD-PERKINS, 1991; VISSER TRAVAGLI, 1992; VISSER TRAVAGLI & WARD-PERKINS, 1981).

Unlike many major Italian towns, Ferrara is not a city of Roman origin, but was settled as Byzantine *castrum* in the 7th century AD (VISSER TRAVAGLI & WARD-PERKINS, 1981) on the left bank of the branch of the Po River active during the early medieval period (the "Po of Ferrara"; BONDESAN *et al*., 1995). Due to its position, the city acted as an important trade centre connecting the Po plain and northern Italy to the Adriatic Sea and consequently flourished since the Middle Ages becoming a main centre in the Renaissance (VISSER TRAVAGLI & WARD-PERKINS, 1981).

Ferrara is located at the apex of the delta plain of the Po River (CASTIGLIONI & PELLEGRINI, 2001), where the distributary channels are highly unstable and likely to switch frequently their course. A major avulsion, known as the "rotta di Ficarolo" (mid-11th century – end of the 12th century AD), caused the main channel of the Po River to migrate to the north, reaching the present position, c. 5 km north of the modern town of Ferrara (VEGGIANI, 1985; BONDESAN *et al*., 1995). After the "rotta di Ficarolo", the Po of Ferrara and its two eastward branches (Po of Volano and Po of Primaro) stayed active and able to generate floods, also due to the input from the Apennine streams, until the beginning of the 16th

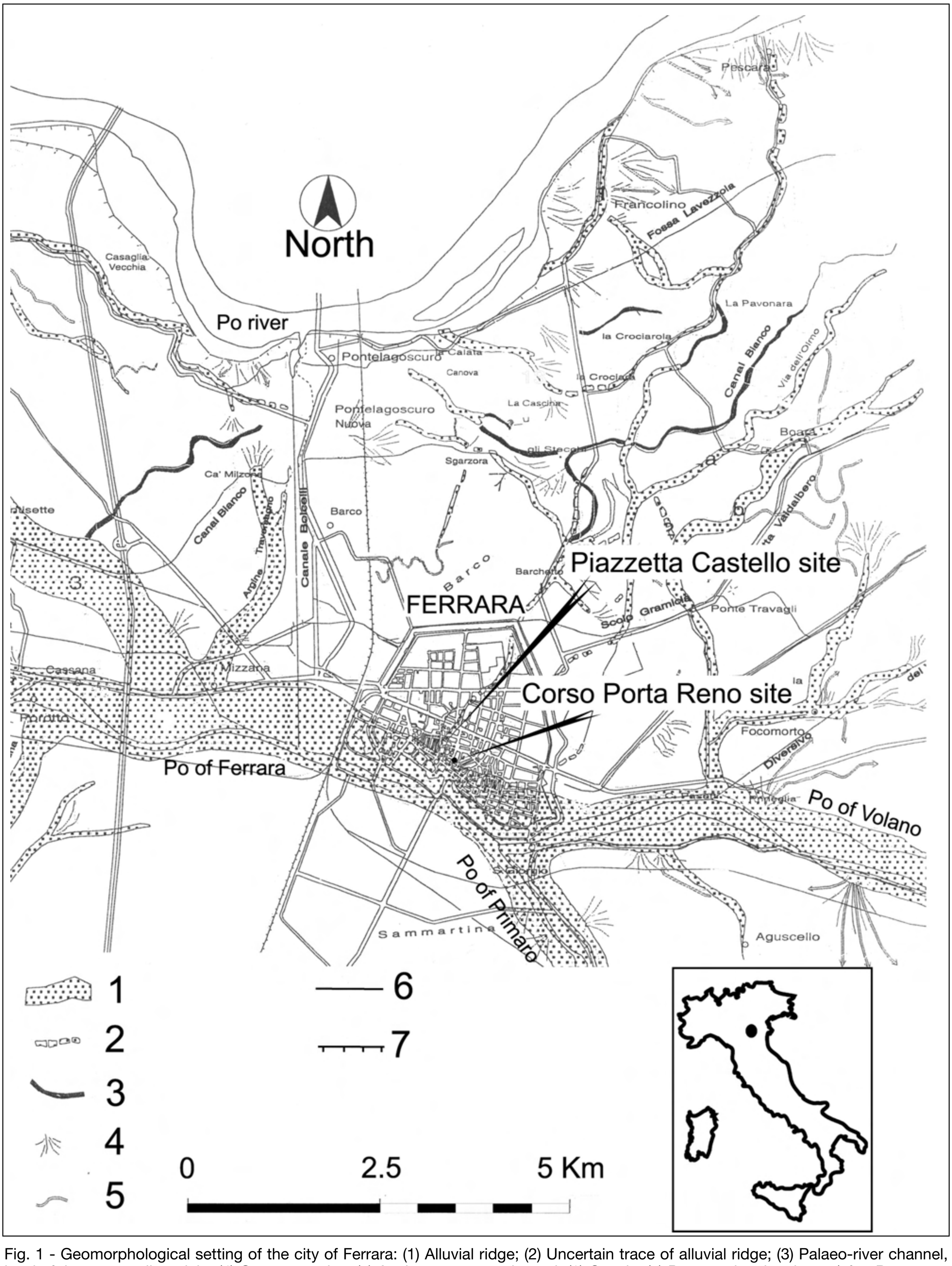

Fig. 1 - Geomorphological setting of the city of Ferrara: (1) Alluvial ridge; (2) Uncertain trace of alluvial ridge; (3) Palaeo-river channel, level of the surrounding plain; (4) Crevasse splay; (5) Ancient crevasse channel; (6) Canals; (7) Present-day river levee (after BONDESAN *et al.*, 1995).

Inquadramento geomorfologico della città di Ferrara: (1) Dosso fluviale; (2) Tracce incerte di dosso fluviale; (3) Paleo-alveo al livello della pianura circostante; (4) Lobo di rotta; (5) Antico canale di rotta; (6) Canali; (7) Argine fluviale attuale (da BONDESAN et al.*, 1995).*

century AD. At this time, the Po of Ferrara was cut off from the active hydrographic network of the area by human intervention (BONDESAN *et al*., 1995).

The position of the Po River channel crossing Ferrara during the medieval period is still evident in the modern topography of the town (STEFANI, this volume). The river flowed, similarly to most of the water courses in this part of the Po plain, on top of a sandy alluvial ridge delimited by natural levees (BRIDGE, 2003), about 4–5 m above the surrounding floodplain (Fig. 1). The latter consists of highly organic clays and peats, as observed by CREMASCHI (1992) in the archaeological excavations at Piazzetta Castello, an area inhabited only after the 13th century AD north of the Po (Fig. 1). Crevasse splays originating from the left side of the river channel were common and can be detected from the elevation models published by BONDESAN *et al*. (1995). The site of the archaeological excavation at Corso Porta Reno is located at the lower fringe of the Po river ridge, in an intermediate position between the latter and the floodplain, possibly at the outer margin of a crevasse-splay fan. The peculiar position of the site allowed an excellent preservation of the archaeological deposits. Wood remains, pertaining to a series of superimposed structural phases were exposed during excavations. These phases were dated by means of the associated material culture between the 8th and the late 13th century. Based on GADD & WARD-PERKINS (1991) and VISSER TRAVAGLI & WARD-PERKINS (1981), the earliest structures exposed at Corso Porta Reno have been interpreted as open-sided temporary sheds, followed by huts with a raised living space above an open-sided ground floor used for storage. A later phase was characterised by timber-framed houses, possibly with an upper storey for domestic activities, with evidence of repeated destruction and reconstruction. Lastly, in the late 13th century, the last timber-framed house was replaced by a brick building. All of the above-mentioned structural phases are characterised, according to the excavators, by an alternating sequence of: *"floors [...] of blue-grey silt and [...] accumulated tread layers interleaved with patches of clean silt reflooring"* (GADD & WARD-PERKINS, 1991, p. 108); or of *"a series of very pure silt deposits separated by charcoal-rich tread layers"* (VISSER TRAVAGLI & WARD-PERKINS, 1979/80, p. 59); or again it was stated that *"these [...] houses underwent refurbishment, indicated by [...] the gradual build-up of tread and reflooring layers"* (GADD & WARD-PERKINS, 1991, p. 112). Making use of soil micromorphology and field observations, the present study is focused on deciphering the sedimentary processes that established the stratigraphic sequence, characteristic of a peri-fluvial urban environment. In particular, this investigation is aimed at identifying the formation processes of both the light-coloured layers, previously interpreted as man-made floors, as well as of the dark anthropogenic layers.

2. MATERIALS AND METHODS

Samples were collected from the stratigraphic profile (Sect. 2) exposed during the 1982 excavation and subsequently integrated by further observations in 1983 (Figs. 2, 3). Sampling has been aimed especially at interpreting the sequence from the stratigraphic and sedimentary standpoint, avoiding anthropic structures.

Thin sections were manufactured from air-dried, undisturbed and oriented blocks according to standard methods (MURPHY, 1986). For thin section description the terminology of STOOPS (2003) was employed, together with the concept of "Soil Microfabric Type[1]" (hereafter SMT) (MACPHAIL & CRUISE, 2001; GOLDBERG & MACPHAIL, 2006)

3. RESULTS

3.1 The stratigraphic section

The studied stratigraphic section is delimited at both sides by brick walls (Figs. 2, 3, 4). The stratigraphic units observed in the field are hereafter briefly described:

3.1.1 Lower layers

They consist of two sub-units: (a) planar organic loamy sand layers, massive or discontinuously laminated with mottles (5Y 4/1dark gray) (Samples 9, 3 – Fig. 3); (b) laminated organic-rich loam layers (5Y 2.5/1, black – 10YR 3/1, very dark gray) rich in charcoal, wood fragments, vegetal residues; they also include large brick fragments and discontinuous lenses of subrounded lithorelictcs with sandy texture. Intercalated to these layers there are lenses of sediments rubefied and hardened due to exposure to fire (Samples 1, 4 – Fig. 3).

3.1.2 Ditch, cesspit and associated deposits

In the stratigraphic profile of Fig. 3, the lower layers are cut by a cesspit related to the timber-framed house. The basal deposit of the ditch consists of peat (Sample 10), rich in wood fragments, sealed by a sandy layer (Sample 8). The cesspit is filled by charcoal and organic rich layers in the lower portion, then by alternating sand and organic-rich sub-units, described below. These alternations are associated with the timber-framed house deposits.

3.1.3 Timber-framed house related deposits

Moving upward in the profile in Fig. 3, we observe a series of planar lenticular layers, concave at the base, as they seal the depression inherited from the underlying ditch. These layers include the structures, the horizontal beams, and the posts pertaining to the timber-framed houses. Two sub-units of contrasting lithology were observed: (a) Medium to fine grained loamy sands, (2.5 YR 5/2 greyish brown); planar laminations, cross laminations and small ripples are often put in evidence by diagenetically oxidised laminae (sample 5). These sub-units do not display evidence of pedological alteration and are devoid of any archaeological material. (b) Loam to loamy silts (from 2.5 Y 3/2, very dark greyish brown, to 5 Y 4/3, olive), massive or displaying discontinuous planar lamination (samples 2 and 6). They include charcoal, wood fragments and archaeological materials (mammal bones and brick

[1] Each SMT corresponds to a set of observed micromorphological characteristics which can occur within different thin sections and are labelled with progressive numbers. Variations within the same SMT are indicated by a small letter (for example SMT 3, 3a).

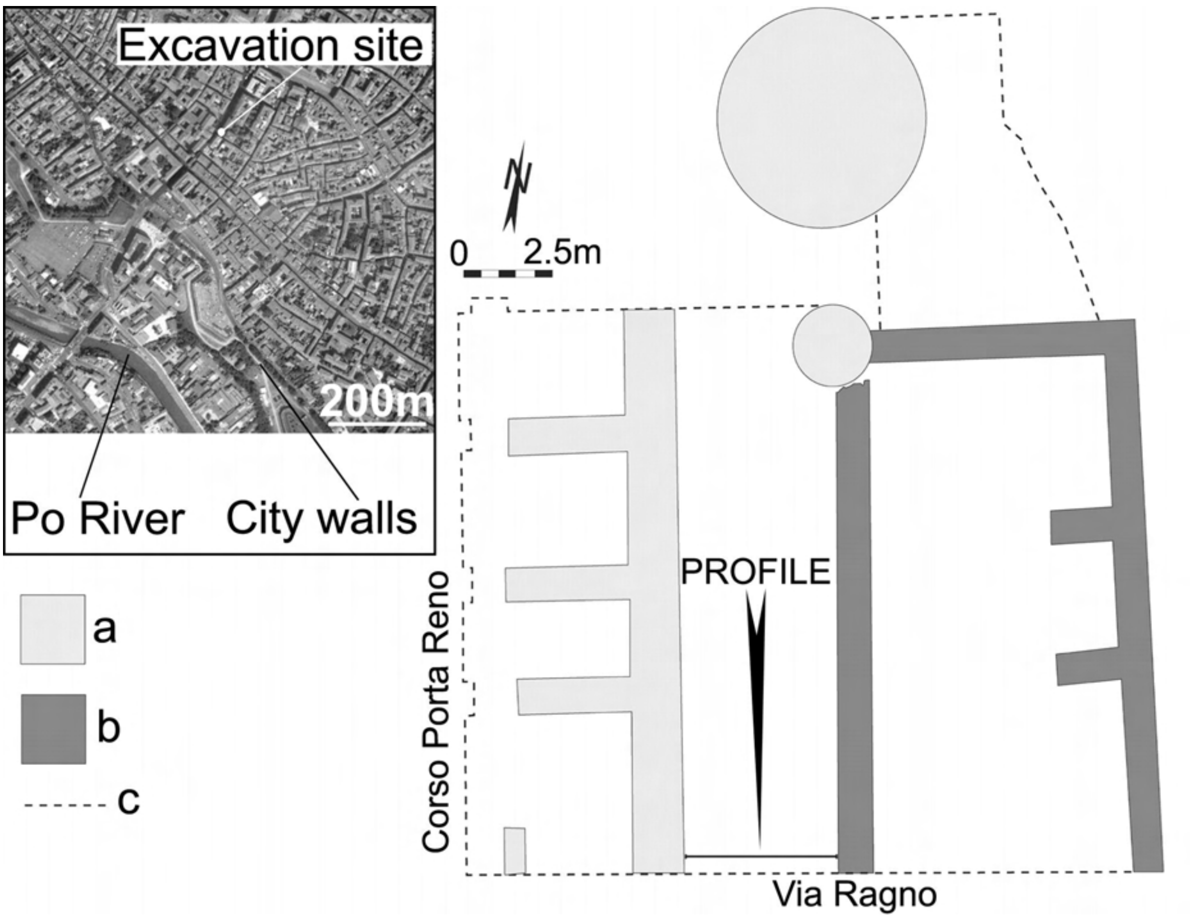

Fig. 2 - Left: location of the Corso Porta Reno excavation in the city of Ferrara. Right: excavation plan with position of the studied profile; (a) modern (19th century) structures (walls, cistern, well), (b) late-13th century brick-house walls; (c) limits of excavated area.

A sinistra: posizione del sito di Corso Porta Reno nella città di Ferrara. A destra: pianta di scavo con posizionamento del profilo esaminato; (a) strutture moderne (XIX secolo): muri, cisterna, pozzo; (b) muri in mattone della case della fine del XIII secolo; (c) limiti dell'area scavata.

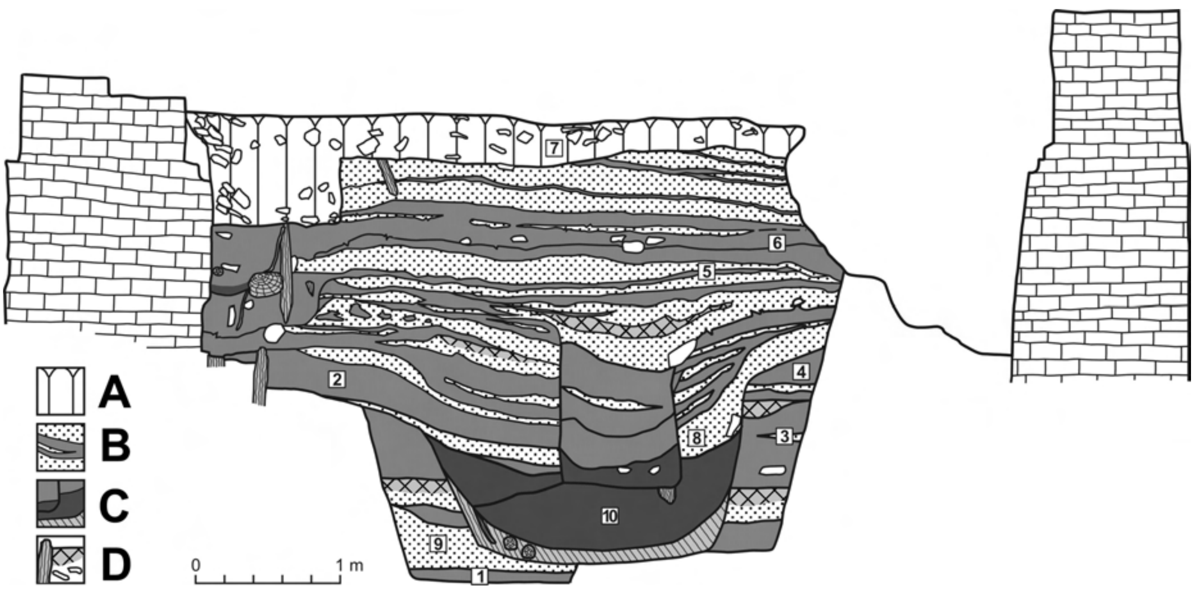

Fig. 3 - The studied stratigraphic profile: (A) Top soil; (B) Alternating lenses of sand (dotted) and loamy organic layers (light grey); (C) Peat deposits and wood; (D) Wood posts, lenses reddened by burning and brick fragments. Numbers on the profile indicate location of thin sections: 1, 9, 3, 4: lower layers; 10, 8: ditch, cesspit and associated deposits; 2, 5, 6: timber-framed house related deposits; 7: top soil.

Il profilo stratigrafico esaminato: (A) Top soil; (B) lenti di sabbia (puntinato) alternate a strati organici a tessitura franca (grigio chiaro); (C) Depositi torbosi e legni; (D) Pali lignei, lenti rubefatte per scottatura e frammenti di mattone. I numeri sul profilo indicano la posizione delle sezioni sottili: 1, 9, 3, 4: strati inferiori; 10, 8: fossato, latrina e relativi depositi; 2, 5, 6: depositi relativi alle strutture abitative in legno; 7: top soil.

Fig. 4 - The studied stratigraphic profile during excavation, with the alternate sequence of light- and dark- coloured layers. To the left the brick wall of the late 13th century AD house can be seen along with wooden structural elements.

Il profilo esaminato durante le fasi di scavo archeologico. Si noti l'alternanza di strati a colorazione chiara e scura. Sulla sinistra sono visibili il muro in mattoni della casa della fine del XIII secolo e degli elementi strutturali lignei.

fragments). Sediments rubefied and hardened by exposure to fire are common, particularly on top of these lenses. In the top part, the stratification dips slightly towards the east and the loamy sandy layers (sub-unit a) increase in number and markedly in thickness.

3.1.4 Topsoil

The topsoil is separated from the underlying unit by an erosional discontinuity. The topsoil consists of silty-clay with common brick and tile fragments; it has mottles (2.5 Y 4/2, dark greyish brown; 7.5 YR 4/4 brown/dark brown), and a weakly separated angular blocky structure with common voids (Sample 7 - Fig. 3).

3.2 Thin section analysis

Tables 1, 2, 3 and 4 provide a brief definition of the observed fabrics and of microstructures, followed by the description of the organic and anthropogenic components, of the groundmass and of the pedofeatures for each SMT occurring in a thin section[2]. An outline of the main characteristics of each Soil Microfabric Type (SMT) identified during thin section analysis is provided below.

SMT 1: sands and silts, often showing sedimentary structures (graded fabric, laminations), almost completely devoid of archaeological materials. It is interpreted as the characterizing microfabric of Po flood deposits, not perturbed by anthropogenic intervention. It has been observed in thin sections 1, 3 (lower units) and 5 (timber-framed house-related deposits). Thin section 9 (lower units) is characterised by SMT 1a, consisting of alluvial sandy-silts reworked by biological activity.

SMT 2: composed almost exclusively of anthropogenic materials (charcoal, mammal and fish bones, excrements, ash, vitrified phytoliths, pottery) with coarser inclusions showing strong horizontal orientation. This microfabric derived from the trampling of deposits produced by domestic activities (hearths, food preparation, dumping of waste etc). The presence of intercalated thin fine-grained lenses and discontinuous laminations testifies the periodic reworking by waters of the exposed dwelling surfaces, probably during floods. SMT 2 has been observed in thin sections 1 (lower units) and 6 (timber-framed house-related deposits).

SMT 3: characterised by the admixture of reworked aggregates deriving from both alluvial layers and from occupation deposits, with components distributed chaotically. Interpreted as the result of the reworking of underlying stratigraphic units during phases of building construction, destruction and/or refurbishing. Excrements and secondary phosphates deriving from cesspit reworking are common. SMT 3 has been

[2] Abundance of fabric units in Tables 1, 2, 3 and 4 is expressed according to STOOPS (2003) as follows: very few (<5%), few (5-15%), common (15-30%), frequent (30-50%), dominant (50-70%).

Table 1 - Lower layers: description of thin sections 1, 3, 4, 9 and associated Soil Microfabric Types (SMT).
Unità inferiori: descrizione delle sezioni sottili 1, 3, 4, 9 e relativi Soil Microfabric Types (SMT).

Thin Sect.	***Depth from top of thin section (mm)***	***Soil Microf. Type (SMT)***	***Micromorphology***	***Interpretation***
1	0-5; 8-10; 15-25	2	Silty clays rich in organic and anthropogenic components. Interbedded discontinuous 500-2000μm-thick silty-clay lenses. Strong horizontal parallel orientation of coarser components. **Microstructure**: massive. **Organic components**: few light brown and dark reddish brown (PPL) vegetal tissue residues; few light brown (PPL) amorphous organic fine material; very few wood tissue fragments; frequent very fine charcoal/charred vegetal fragments; common fine charcoal fragments; few coarse charcoal fragments. **Anthropogenic components**: very few burned and unburned bones; very few ash aggregates; very few vitrified phytoliths. **Groundmass**: light grayish brown (PPL) calcareous and charcoal-rich clays with crystallitic b-fabric. **Pedofeatures**: very few Fe coatings around coarse charcoal fragments.	Trampled and compacted occupation deposit deriving from domestic activities (for example functioning and cleaning of hearths), with traces of redistribution by water in a low-energy sedimentary environment.
	5-8; 10-15; 25-40	1	Alternation of 5-10mm-thick laminae of well-sorted sandy silt and of silty clay. **Microstructure**: massive. **Organic components**: very few very fine charcoal fragments. Groundmass: yellowish brown (PPL) with parallel-striated b-fabric (silty clays); crystallitic b-fabric (sandy silts). **Pedofeatures**: very few Fe-phosphatic nodules, often associated to vivianite crystal intergrowths.	Natural alluvial deposit, in one case disturbed/reworked (10-15mm).
3	0-60	1	Same as thin section 1 (SMT 1) but more dominantly sandy-silty	Natural alluvial deposit.
4	0-45	3	Same as thin section 2 (SMT 3 – see Tab. 2) but: microstructure is weakly-developed vughy. Reworked SMT1 rounded aggregates are few. **Anthropogenic components:** common burned and unburned bones and fishbone; very few eggshell fragments; very few vitrified phytoliths. **Pedofeatures**: very few Fe-phosphatic nodules.	Layer deriving from reworking of underlying deposits; predominance of components deriving originally from domestic activities. (hearth functioning and cleaning – SMT 2)
9	0-60	1a	Sandy silts with no sedimentary structures. **Microstructure**: moderately developed channel microstructure. **Organic components**: very few very fine charcoal/charred vegetal fragments; very few fine charcoal fragments. **Anthropogenic components**: very few burned bone fragments; very few carnivore/omnivore excrements. **Groundmass**: light yellowish brown (PPL) clays with stipple-speckled b-fabric. **Pedofeatures**: few Fe-phosphatic nodules, orthic. Common passage features with crescent-like related distribution.	Biologically reworked sandy-silty layer, with very rare anthropogenic components.

observed in samples 4 (lower units), 2 and 6 (timber-framed house-related deposits), 7 (topsoil). SMT 3a has been assigned in thin section 6 to a sub-unit showing traces of trampling and compaction. SMT 3b derived from the weathering and bioturbation of SMT 3 and was observed in thin section 7 (topsoil).

SMT 4: Silty-clay textured material with common plant remains showing strongly-expressed parallel horizontal orientation. Intercalated lenses that can be silty-clayey or made up by phosphates or ash. Frequent archaeological components (charcoal, bones and fish-bones, excrements). Interpreted as the outcome of stagnation within the ditch accompanied by the occasional dumping of waste. It has been observed in thin sections 8 and 10 (ditch, cesspit and associated deposits).

3.2.1 Lower layers (thin sections 1, 9, 3, 4 – Table 1)

Thin Section 1 is an example of the sequence interpreted by Gadd & Ward-Perkins (1991) and Visser Travagli & Ward-Perkins (1979/80) as the alternation of dark "thread" layers and yellowish "reflooring". Under the microscope (Fig. 5A), the sample is made up of 2-15mm thick levels of well sorted laminated sandy silts and silty clays, sometimes showing graded fabric (SMT 1), intercalated to 2-5mm-thick trampled occupation layers (SMT 2). The presence of sedimentary structures (Fig. 5C) allows us to interpret the material labelled as SMT 1 as a series of thin alluvial levels, natural in origin, rather than as man-made reflooring layers.

Only one of these layers appears devoid of sedimentary structures (thin section 1), possibly due to

Table 2 - Ditch, cesspit and associated deposits: description of thin sections 8 and 10 and associated soil microfabric types (SMT).
Fossato, latrina e relativi depositi: descrizione delle sezioni sottili 8 e 10 e relativi Soil Microfabric Types (SMT).

Thin Sect.	*Depth from top of thin section (mm)*	*Soil Microf. Type (SMT)*	*Micromorphology*	*Interpretation*
8	0-30	3	Layer composed dominantly of reworked aggregates of SMT 1 material, few reworked aggregates of SMT 2 material and very few reworked aggregates of SMT 4 material. Coarse organic and anthropogenic components are chaotically distributed. **Microstructure**: massive. **Organic components**: frequent dark brown (PPL) tissue fragments; very few dark reddish brown (PPL) organ residues. Few fine charcoal fragments; few very fine charcoal/charred vegetal fragments. **Anthropogenic constituents**: very few burned and unburned bone fragments and fishbones; very few ash aggregates. **Groundmass**: light yellowish brown calcareous clays with crystallitic b-fabric (dominant). **Pedofeatures:** Traces of Fe-phosphatic nodules, orthic.	Layer deriving from reworking of underlying deposits (pits, post-holes, trenches) dumped in the ditch. Presence of SMT 4 material.
	30-45	4	Silty-clay textured layer with common elongated and horizontally-lying plant residues. Occasional intercalated discontinuous phosphatic or ash-rich levels (1-2mm thick). **Microstructure**: massive (dominant); locally weakly separated platy. **Organic components**: common dark reddish brown and dark brown (PPL) tissue residues; few dark reddish brown (PPL) organ residues; frequent organic matter punctuations. Common very fine charcoal/charred vegetal fragments; common fine charcoal fragments. **Antrhopogenic constituents**: few unburned bone fragments and fishbone; frequent ash aggregates; very few burned soil aggregates; few carnivore/omnivore excrements. **Groundmass:** light yellowish brown (PPL) calcareous clays with crystallitic b-fabric; white/yellowish (PPL) phosphatic levels, optically isotropic; dark grey (PPL) ash levels with crystallitic b-fabric. **Pedofeatures**: absent.	Layer composed mostly of plant residues and reworked anthropogenic components, deposited in standing water inside the ditch. Occasional inputs of ash and phosphatic material (from cesspits and latrines).
10	0-60	4	1.5-2cm thick bands of SMT 4 material (see thin section 8, above) separated by continuous clay or silty-clay lenses showing laminations and occasionally internal grading.	Layer composed mostly of plant residues and reworked anthropogenic components deposited in standing waters inside the ditch. Fine-grained laminated and graded sediment lenses intercalated.

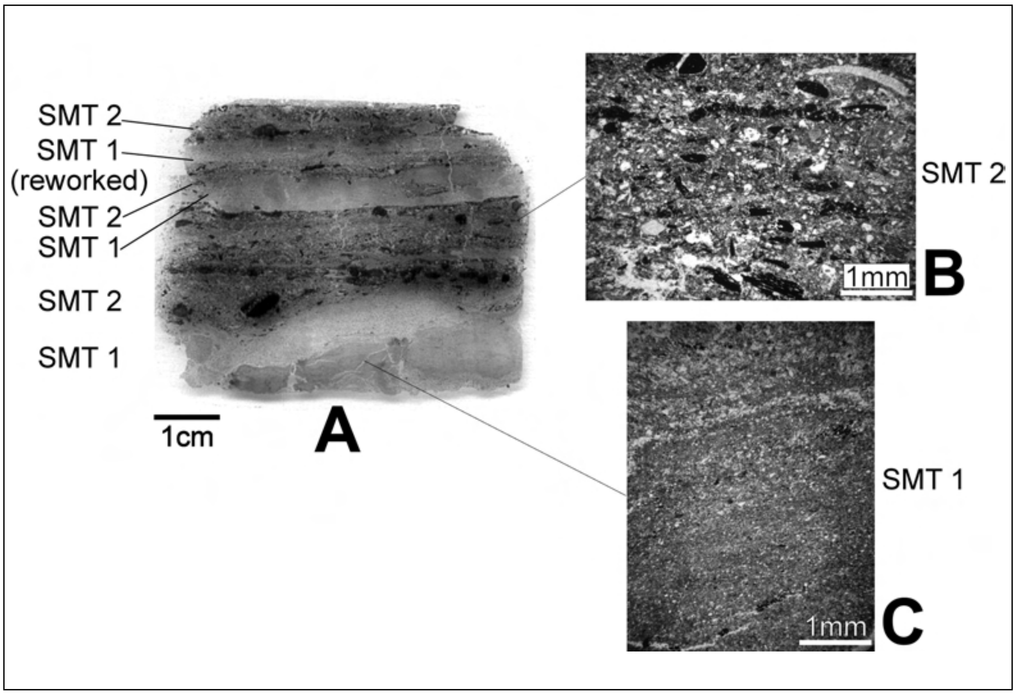

Fig. 5 - Lower layers, thin section 1. The scanned thin section (A) shows the alternating sequence of laminated alluvial sands and silty clays characterised SMT 1 (C, 20x) and of occupation deposits characterised by SMT 2 (B, 20x). In the latter, the strong parallel horizontal orientation of coarser constituents and the massive microstructure are linked to trampling and compaction.

Unità inferiori, sezione sottile 1. La sezione sottile scannerizzata (A) evidenza l'alternanza di sabbie/argille limose alluvionali caratterizzate da SMT 1 (C, 20x) e di depositi di frequentazione caratterizzati da SMT 2 (B, 20x). In questi ultimi l'iso-orientamento delle componenti grossolane e la microstruttura massiva sono legate al calpestio e alla compressione.

Table 3 - Timber-framed house related deposits: description of thin sections 2, 5, 6 and associated soil microfabric types (SMT).
Depositi associati alle strutture abitative in legno: descrizione delle sezioni sottili 2, 5, 6 e relativi Soil Microfabric Types (SMT).

Thin Sect.	***Depth from top of thin section (mm)***	***Soil Microf. Type (SMT)***	***Micromorphology***	***Interpretation***
2	0-45	3	Organic-rich clayey-silts with frequent reworked sub-rounded SMT1 inclusions. Chaotic organization of coarse fabric constituents. **Microstructure**: massive. **Organic components**: very few reddish-brown (PPL) elongated vegetal tissue fragments. Very few dark reddish-brown (PPL) wood fragments. Very few amorphous fine organic material (light brown in PPL). **Anthropogenic components**: very few burned bones; few ash aggregates; few subrounded burned soil fragments; very few carnivore/omnivore excrement fragments; common very fine charcoal/charred vegetal fragments; few fine charcoal fragments. **Groundmass**: SMT 2 aggregates are dark grayish brown (PPL) with crystallitic b-fabric. SMT 1 aggregates are yellowish brown (PPL) with crystallitic b-fabric. **Pedofeatures**: few Fe-phosphatic nodules, occasionally associated to vivianite crystal intergrowths.	Layer deriving from reworking of underlying deposits (for example pits, post-holes, trenches) during building destruction, construction and/or refurbishing phases. Presence of phosphatic materials and deriving from latrines and cesspits.
5	0-55	1	Same as thin section 3 (SMT 1) but silty-sandy in texture.	Natural alluvial deposit.
6	0-20	2	Same as SMT 2 in thin section 2, except for: **Organic components:** frequent fine charcoal fragments; no coarse charcoal fragments. **Anthropogenic components:** few ash aggregates. **Pedofeatures**: traces of Fe-phosphatic nodules.	Trampled and compacted occupation deposit deriving from domestic activities (functioning and cleaning of hearths).
	20-30	3	Same as thin section 2 (SMT 3) except for: frequent reworked aggregates of SMT 1 material. **Anthropogenic components:** few burned and unburned bone fragments and fishbone; no burned soil fragments; no excrement fragments. **Pedofeatures:** no Fe-phosphatic nodules. Very few Fe/Mn coatings around large charcoal fragments, strong impregnation.	Chaotic layer deriving from building destruction/construction activities and from digging of underlying deposits (for example pits, post-holes, trenches). Materials from latrines and/or cesspits are absent.
	30-45	3a	Silty clays rich in anthropogenic components showing strong parallel horizontal orientation of coarser constituents. Few reworked aggregates of SMT 1 material in the top part. **Microstructure:** massive. **Organic components**: very few elongated dark reddish-brown (PPL) tissue residues; traces of reddish brown (PPL) organ residues; very few dark reddish brown (PPL) organic punctuations. Frequent very fine charcoal/charred vegetal fragments; few fine charcoal fragments; few coarse charcoal fragments. **Anthropogenic components**: very few burned/unburned bone fragments and fishbone; common ash aggregates; very few burned soil aggregates. **Groundmass:** light brownish gray (PPL) ash-rich groundmass with crystallitic b-fabric. **Pedofeatures:** impure clay micropan, continuous, laminated with convolute laminae, 2-4mm thick, occurring at the top of the level.	Layer deriving from reworking of underlying deposits (pits, post-holes, trenches) during building destruction, construction and/or refurbishing phases. Presence of surface exposure and associated traces of trampling and compaction.

Table 4 - Top soil: description of thin section 7 and associated soil microfabric type (SMT).

Top soil: descrizione della sezione sottile 7 e relativo Soil Microfabric Type (SMT).

Thin Sect.	***Depth from top of thin section (mm)***	***Soil Microf. Type (SMT)***	***Micromorphology***	***Interpretation***
7	0-45	3b	Same as SMT 3 in thin section 2, except for: very few reworked aggregates of SMT 1 material. **Microstructure**: moderately developed channel microstucture. **Organic components:** few elongated dark reddish brown (PPL) tissue residues; very few light reddish brown (PPL) organ residues; very few dark brown (PPL) amorphous organic matter. Common very fine charcoal/charred vegetal fragments; common fine charcoal fragments; few coarse charcoal fragments. **Anthropogenic components:** common burned and unburned bone fragments and fishbone; traces of ash aggregates; very few pottery fragments; very few burned soil fragments; very few omnivore/carnivore excrements. **Pedofeatures:** absent.	Layer deriving from reworking of underlying deposits (pits, post-holes, trenches) during building destruction, construction and/or refurbishing phases. Presence of phosphatic materials and deriving from latrines and cesspits. Traces of weak pedogenesis.

trampling disturbance (Fig. 5A). The occupation layers with SMT 2 microfabric are rich in plant residues and in anthropogenic components. These consist of large quantities of charcoal of all sizes, burned bone, ash aggregates and vitrified phytoliths (deriving from the melting of biogenic opal - Courty *et al*. 1989), symptomatic of materials from the functioning and maintenance of domestic hearths. Fishbones are widespread in all thin sections from occupation deposits, suggesting the exploitation of the nearby river Po for subsistence, even though detailed studies on the faunal remains are not yet available. The massive microstructure and the horizontal orientation of coarser constituents (charcoal, elongated plant material, bones) indicate that these levels were subject to trampling and compaction (Fig. 5B). Evidence of flood reworking on the exposed dwelling surfaces were also observed, such as rare fine-grained lenses and the sorting of charcoal fragments toward the top of each layer.

Thin sections 3 and 9 are from sandy-silt layers almost devoid of anthropogenic inclusions. Thin section 3 is interpreted as a natural alluvial deposit (SMT 1), confirming the occurrence of floods during this phase. The origin of the sandy silts in thin section 9 is more difficult to establish, since the sample is strongly reworked by biological activity, as shown by the channel microstructure and the widespread passage features (SMT 1a). Anthropogenic components such as charcoal, burned bone and excrement fragments are however very rare in this thin section.

Thin section 4 is characterised by SMT 3 microfabric, consisting of an admixture of different materials, with a chaotic organisation of the components and no trace of trampling or compaction (Fig. 6). This microfabric type encompasses reworked aggregates of the occupation layers described above (SMT 2 microfabric), together with frequent subrounded aggregates of alluvial sediments (SMT 1 – Fig. 6A). This material can thus be interpreted as the outcome of the destruction by digging and the reworking of underlying deposits. This process resulted in a chaotic mixture of aggregates and fragments from different stratigraphic units. Orange-yellowish (plane polarized light - PPL) aggregates, optically isotropic under crossed nichols, containing phytoliths and occasional small fragments of bone, are interpreted as carnivore/omnivore excrements (Macphail 2000), possibly of human origin (Fig. 6A). Orange-yellowish (PPL) optically isotropic orthic and disorthic nodules, often associated with vivianite crystal intergrowths, are also present in thin sections 4 and 2, and can be interpreted as Fe-phosphatic nodules (Fig. 6B). These nodules, the crystal intergrowths and the excrements derive most likely from the destruction or rebuilding of cesspits and latrines. Several phases of cesspit construction and refurbishing have indeed been recorded during archaeological excavations (Gadd & Ward-Perkins, 1991).

3.2.2 Ditch, cesspit and associated deposits (thin sections 8, 10 – Table 2)

Thin sections 8 and 10 are mainly composed of elongated plant fragments, among which leaves are frequently recognisable (Figs. 7A, 7B - SMT 4 microfabric). These vegetal residues show a horizontal parallel orientation, locally resulting in a platy microstructure. Discontinuities within plant residue levels are marked by ash-rich or phosphatic 1-2mm thick discontinuous layers (especially in thin section 8), or by continuous, laminated or graded thin silty-clay lenses (thin section 10 – Fig. 7C). The lenses most likely correspond to fine-grained mineral layers, intercalated to the organic materials through deposition in a low-energy environment. We interpret this portion as the deposition in standing waters inside the ditch cut from the base of the timber-framed house-related deposits (Fig. 3). Along the sides of the ditch dumping of ashes, cess material and construction rubble (observed in thin section 8) took place.

3.2.3 Timber-framed house-related deposits (thin sections 2, 5, 6 – Table 3)

Micromorphology shows that the deposits associated to the timber-framed house consist of alternation of materials deriving from trampled occupation layers and from building destruction and refurbishing. These

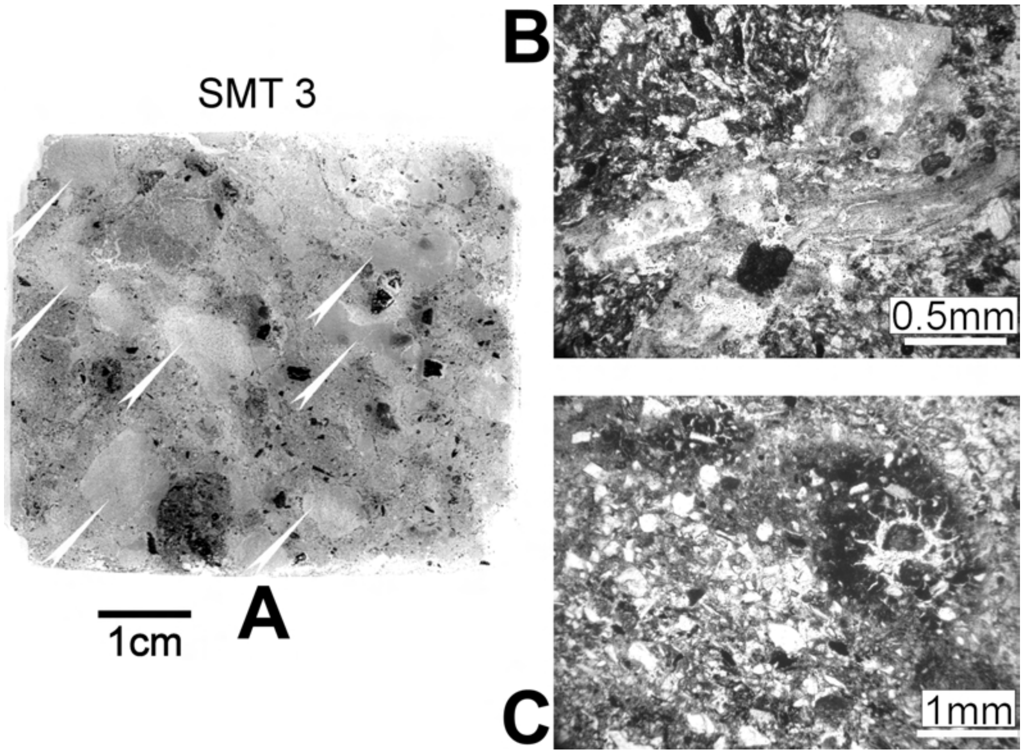

Fig. 6 - Lower layers, thin section 4. SMT 3 derives from the reworking of underlying deposits with inclusions of cesspit materials. In the scanned thin section (A) arrows point at the reworked aggregates from underlying alluvial layers (SMT 1 material). The occurrence of carnivore/omnivore excrement fragments (B, 40x PPL) and of Fe-phosphatic nodules (C, 20x PPL) testifies to the input of materials from cesspits.

Unità inferiori, sezione sottile 4. SMT 3 deriva dal rimaneggiamento dei depositi sottostanti, con immissione di materiale derivante da latrine. Nella sezione sottile scannerizzata (A) le frecce indicano aggregati rimaneggiati provenienti dalle unità alluvionali sottostanti (materiale con SMT 1). Frammenti di escrementi di carnivori/onnivori (B, 40x PPL) e noduli ferro-fosfatici (C, 20x PPL) testimoniano la presenza di materiali derivanti da latrine.

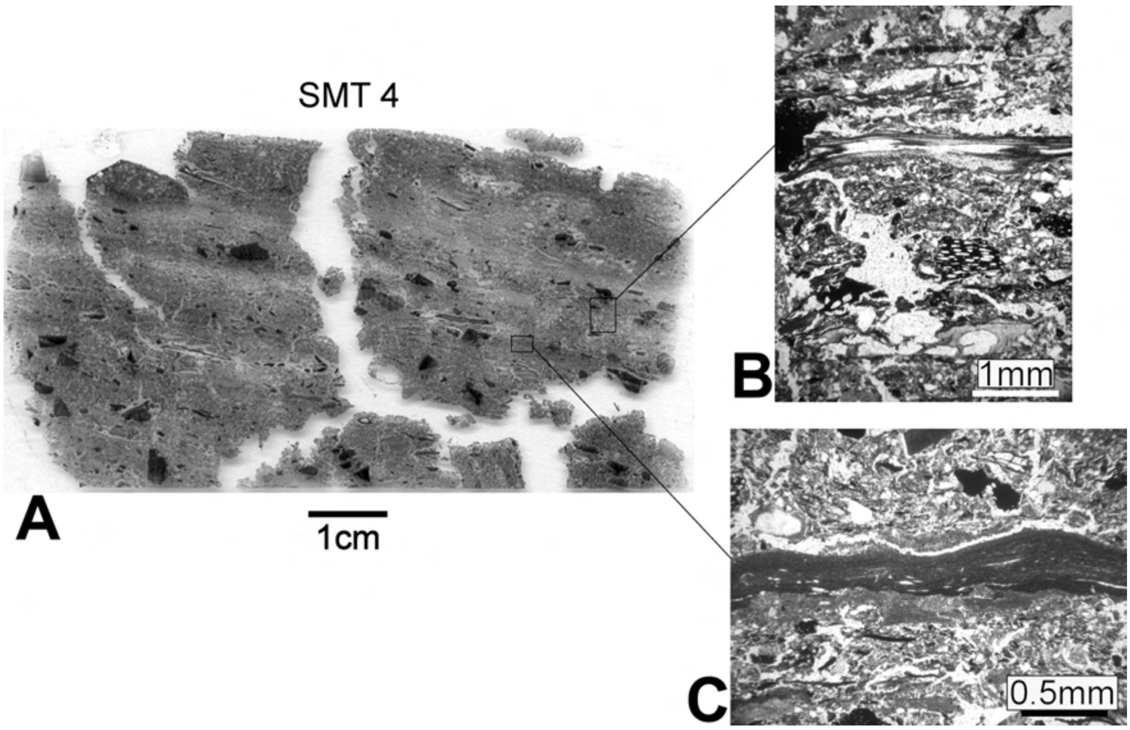

Fig. 7 - Ditch, cesspit and associated deposits, thin section 10. In the scanned thin section (A) it is possible to observe the layering that characterises the filling of the ditch. (B): layered plant remains and charcoal, characteristic of SMT 4 (20x PPL). (C): detail of one of the fine sediment lenses intercalated to the organic layers in SMT 4 (40x PPL).

Fossato, latrina e depositi associati, sezione sottile 10. Nella sezione sottile scannerizzata (A) è possibile osservate la stratificazione che caratterizza il riempimento del fossato. (B): residui vegetali e carboni stratificati, tipici di SMT 4 (20x, PPL). (C): dettaglio di una delle lenti di sedimento fine intercalate agli strati a componenti organiche in SMT 4 (40x PPL).

deposits bear traces of reworking by flood water flows. Thin section 2 provides another example of a layer deriving from digging and reworking of underlying deposits during building destruction or refurbishing. The layer shows the chaotic disposition of coarse organic and anthropogenic constituents (SMT 3) and the frequent occurrence of reworked sandy-silty aggregates of alluvium (SMT 1 material). Destruction and refurbishing of buildings followed by occupation was observed also in thin section 6. Here, the admixture of reworked materials from underlying units shows traces of trampling and compaction, such as the parallel horizontal orientation of coarser constituents and a massive microstructure (SMT 3a). In the same thin section, there are traces of further deposition of SMT 3 material and then again of the formation of a trampled occupation layer.

Thin section 5 pertains to silty-sands interpreted as a natural alluvial deposit, as shown by the presence of internal laminations and graded fabric. The field observation of planar laminations, small ripple forms and cross-laminations fits with the microscopic evidences.

3.2.4 Topsoil (thin section 7 – Table 4)

This layer predates the construction of the brick house at the end of the 13th century and contains abundant coarse construction debris, such as brick and tiles. Thin section 7 is a chaotic admixture of materials, deriving from the destruction and refurbishing of buildings, and has a weakly developed channel microstructure. The latter suggests that biological reworking by earthworms took place during a phase of topsoil formation, during which the surface was dry and stable (SMT 3b).

4. DISCUSSION

The site of Corso Porta Reno in Ferrara offered an important opportunity to investigate the modes of formation and accretion of an urban stratigraphic sequence in a medieval town. In cities throughout Europe, archaeological excavations have often exposed deposits referred to as “Dark Earths” (see CARVER, 1987; BROGIOLO *et al*., 1988; YULE, 1990; MACPHAIL *et al*, 2003; GALINIÉ, 2004). Dark Earth is a term used to designate thick, seemingly homogeneous and dark-coloured deposits rich in archaeological material, generally ascribed to the post-Roman period. Since the early 1980s (MACPHAIL 1981, 1983), geoarchaeological and especially soil micromorphological analyses have demonstrated that in many cases Dark Earth represents an once-complex deposit that has been heavily homogenised by pedological processes, especially bioturbation and weathering (MACPHAIL, 1994; MACPHAIL & GOLDBERG, 1995). Geoarchaeological analyses revealed that many diverse, superimposed activities and processes are responsible for the formation of urban Dark Earths. These correspond, for example, to the repeated dumping of waste (CAMMAS, 2004), cultivation (CREMASCHI, 1992), human dwelling, stabling of animals and decay of insubstantial buildings (MACPHAIL & GOLDBERG, 1995), among others. Due to human reworking, to the action of rodents, earthworms, enchytraeds, plant roots, and weathering of organic and earth-based construction materials, any macroscopic original sedimentary structure and stratification has been obliterated. At Corso Porta Reno the persisting waterlogged conditions and the rapidly aggrading sedimentary environment prevented the deposit from being disturbed and homogenized by soil fauna or by roots. In a later phase, the presence of the topsoil (sample 7) witnesses the interruption of sedimentary processes, replaced by weathering. The whole sequence was then sealed in the 13th century AD by the construction of a brick house that remained in place until its destruction in the last war (GADD & WARD-PERKINS, 1991). All these factors enabled the original stratification of the deposit to be preserved.

Macro- and micro-morphological investigation indicates that the anthropic accretion at the site is mostly the outcome of: (a) trampling of domestic deposits (SMT 2), generated by the activity of fireplaces as also shown by the occurrence of surfaces reddened by burning. Flood reworking occasionally took place (see below); (b) construction, destruction or refurbishing of buildings (SMT 3) marked by digging of underlying deposits (post-holes, pits, cesspits); (c) sediment settling inside negative structures (ditch, cesspits) producing organic levels with intercalated fine-grained sediment lenses (SMT 4). Within such structures occasional dumping of construction rubble, ash and cesspit material could take place, as well as the filling by fluvial sediments.

The natural alluvial deposits are intercalated to anthropogenic ones mainly in the phase of the timber-framed house, their thickness increasing markedly towards the top of the sequence.

Alluvial deposits can be classified into two types: (a) layers of well sorted medium-fine sand or silty-sand with cross-laminated structures, deposited in crevasse splays, due to floods breaching from the Po River channel (SMT 1); (b) organic-rich silt and fine sand, including charcoal, wood fragments deriving from decantation and redistribution of materials in a waterlogged environment (fine-grained lenses in SMT 2). These deposits are often intercalated to anthropogenic surfaces related to trampling, recording water content fluctuation, possibly on a seasonal base. In the study area, floods are mainly expected during the autumn and early spring.

These stratigraphic information fit well with the observations made during the archaeological excavation, which indicate that before the brick house of the late 13th century, buildings were mostly two-storey timber houses, with an open ground floor. Fireplaces at the ground floor were frequent and often rebuilt and moved. The houses underwent several phases of rebuilding, refurbishing and even destruction by fire (GADD & WARD-PERKINS, 1991; VISSER TRAVAGLI & WARD-PERKINS, 1979/80). Not all of the “clean” silty and sandy-silty layers appear to be man-made reflooring layers (see § 1). Based on field and microscopic evidence, these layers could rather be interpreted as natural alluvial deposits intercalated to occupation or “thread” layers. The presence of flood beds intercalated to occupation deposits has important bearings for the understanding of the urban stratigraphy. It shows that in cities located close to active rivers (e.g. on top of active alluvial ridges or in floodplains) part of the accretion can be linked to the episodic input of alluvium or to deposition and redistribution in standing waters.

Alluvium and occupation deposits will normally be subject to weathering, homogenisation by syn- and post-depositional bioturbation and human reworking (e.g. cultivation, digging, construction of buildings), unless these processes are hampered. While in need of further research, this model could partly account for the strong vertical accretion and for the formation of homogeneous "Dark Earths" in medieval cities within active fluvial environments.

5. CONCLUSIONS

The geoarchaeological investigation of the stratigraphic sequence of the Corso Porta Reno site, in Ferrara, has proven useful for both archaeological-historical and geomorphologic purposes. It elucidated the natural and anthropic processes leading to the formation of thick urban stratigraphic sequences. In doing so, it revealed that accretion derives from the superimposition of trampled domestic occupation deposits and activity surfaces, of chaotic layers deriving from building construction activities, of organic-rich facies formed within negative structures with standing waters, and of flood deposits from the Po of Ferrara. Given the proximity to the alluvial ridge, the alluvial deposits, with their generally sandy texture and cross-laminated sedimentary structures, can be explained in a crevasse splay context, which has been observed in all the units of the stratigraphic sequence, except for unit "topsoil" (Unit A in Fig. 3, see § 3.1.4).

The waterlogged nature and the strongly aggrading environment of the site avoided the effects of bioturbation, allowing this exceptional sequence to be very well preserved and readable. It therefore seems clear that at the site the vertical growth of the urban deposit resulted from the interplay between alluvial sedimentation close to the Po ridge and repeated episodes of human occupation, possibly with a seasonal character. The model of formation envisaged in Corso Porta Reno should be investigated for urban sites with Dark Earth-like deposits located in an active alluvial setting.

The results of the study of the Corso Porta Reno stratigraphic profile, integrated with data from archaeological excavations, showed that, in the early medieval period structure types, construction techniques and modes of occupation were adapted to a peri-fluvial environment. The change in the style of the sedimentation towards the top of the sequence, highlighted by the bioturbated and well-drained character of the topsoil (Fig. 3), seems to be correlated with an important change in the sedimentary environment of the urban area. This corresponds to the shift from a setting subject to seasonal floods to one in which sedimentary processes appear to be somewhat under control. This latter process might have an anthropic origin, like the increased control of levees, but might also be related to the major change in the hydrography of the Po floodplain associated with the "rotta di Ficarolo" avulsion (mid-11th century – end of the 12th century AD - Veggiani, 1985; Bondesan *et al*., 1995). This avulsion led in fact to the progressive abandonment of the channel of the Po of Ferrara, which flowed through the city until that moment.

6. ACKNOWLEDGEMENTS

For the involvement in the Corso Porta Reno excavation Mauro Cremaschi wishes to express his gratitude to Dr. A. M. Visser Travagli.

7. REFERENCES

Bondesan M., Ferri R., Stefani M. 1995 - *Rapporti fra lo sviluppo urbano di Ferrara e l'evoluzione idrografica, sedimentaria e geomorfologica del territorio.* In: Visser Travagli A. M. (Ed.), Ferrara nel Medioevo. Topografia storica e archeologia urbana, Grafis Edizioni, Casalecchio di Reno, 27-42.

Bridge J. S. 2003 - *Rivers and floodplains: forms, processes and sedimentary record.* Wiley-Blackwell, Malden, MA, U.S.A.

Brogiolo G.P., Cremaschi M., Gelichi S. 1988 - *Processi di stratificazione in centri urbani (dalla stratificazione "naturale" alla stratificazione "archeologica")*. Archeologia stratigrafica dell'Italia Settentrionale, **1.** Edizioni New Press, Como, 219-226.

Carver M.O.H. 1987 - *The nature of urban deposits*. In: Schofield J., Lynch R. (Eds.) - Urban Archaeology in Britain, CBA Research Report 61, London, 9-26.

Castiglioni G. B., Pellegrini M. (Eds.) 2001 - *Note illustrative della carta geomorfologica della Pianura Padana*. Suppl. Geografia Fisica e Dinamica Quaternaria, **IV**, 1-204.

Courty, M. A., Goldberg P., Macphail R.I. 1989 - *Soil micromorphology in archaeology*. Cambridge Manuals in Archaeology, Cambridge University Press, Cambridge.

Cremaschi M. 1992 - *Caratteristiche geoarcheologiche della successione stratigrafica posta in luce nello scavo archeologico di Piazzetta Castello*. In: Gelichi S. (Ed.), Ferrara prima e dopo il Castello. Testimonianze archeologiche per la storia della città, Spazio Libri Editori, Ferrara, 58–65.

Gadd D., Ward Perkins B. 1991 - *The development of urban domestic housing in North Italy. The evidence of excavations on the San Romano site, Ferrara*. The Accordia research papers, **2,** 105–127.

Galinie H. 2004 - *L'expression "terres noires", un concept d'attente*. In: Verslype L., Brulet R. (Eds.), Terres noires - dark earth. Actes de la table-ronde internationale tenue à Louvain-la-Neuve les 09 et 10 Novembre 2001, Universitè catholique de Louvain, Louvain-la-Neuve.

Goldberg P., Macphail R. I. 2006 - *Practical and theoretical geoarchaeology.* Blackwell Publishing, New York.

Macphail R.I. 1981 - *Soil and botanical studies of the "Dark Earth"*. In: Jones M. & Dimbleby G.W. (Eds.), - *The environment of man: the Iron Age to the Anglo-Saxon period*. British series, **87.** British Archaeological Reports, Oxford, 309–331.

Macphail R.I. 1983 - *The micromorphology of dark earth from Gloucester, London and Norwich: an analysis of urban anthropogenic deposits from Late Roman to early Medieval periods in England*. In: Bullock P., Murphy C.P. (Eds.), Soil Micromor-

phology. AB Academic Publishers, Berkhamsted.
MACPHAIL R.I. 1994 - *The reworking of urban stratigraphy by human and natural processes*. In: HALL A.R. & KENWARD H.K. (Eds.), Urban-rural connexions: perspectives from environmental archaeology. Oxbow Monographs, **47**, Oxford, 13–43.
MACPHAIL R. I. 2000 - *Soils and microstratigraphy: a soil micromorphological and microchemical approach*. In: LAWSON A.J. (Ed.), Potterne 1982-5: animal husbandry in later prehistoric Wiltshire, Wessex Archaeology Report, 17, Salisbury, 47–71.
MACPHAIL R. I., GOLDBERG P. 1995 - *Recent advances in micromorphological interpretations of soils and sediments from archaeological sites*. In: BARHAM A. J., MACPHAIL R. I. (Eds.), Archaeological sediments and soils: analysis, interpretation and management, Institute of Archaeology, London, 1–24.
MACPHAIL R. I., CRUISE J. 2001 - *The soil micromorphologist as a team player – a multyanalytical approach to the study of European microstratigraphy*. In: GOLDBERG P., HOLLIDAY V. T., REID FERRING C. (Eds.), Earth Sciences in Archaeology, Kluwer Academic/Plenum Publishers, 241–267.
MACPHAIL R.I. GALINIÉ H., VERHAEGHE F. 2003 - *A future for dark earth?*. Antiquity, 77 (**296**), 349–358.
MURPHY C.P. 1986 - *Thin Section Preparation of Soils and Sediments.* AB Academic, Berkhamsted.
VEGGIANI A. 1985 - *Il delta del Po e l'evoluzione della rete idrografica padana in epoca storica*. In: *Atti della tavola rotonda: Il Delta del Po, Sezione Geologica*. Accademia delle Scienze dell'Istituto di Bologna, 39–68.
VISSER TRAVAGLI A. M., WARD PERKINS B. 1979/80 - *Archeologia urbana a Ferrara: scavi nel comparto di S. Romano, 1981*. Bollettino Annuale dei Musei Ferraresi, **9/10**, 55–58.
VISSER TRAVAGLI A. M. 1992 - *Lo scavo nel comparto di S.Romano: analisi di un' esperienza archeologica*. In: GELICHI S. (Ed.), Ferrara prima e dopo il Castello. Testimonianze archeologiche per la storia della città. Spazio Libri Editori, Ferrara, 248–259.
STOOPS G. 2003 - *Guidelines for analysis and description of soil and regolith thin sections*. Soil Science Society of America, Madison, WI.
YULE B. 1990 - The "dark earth" and late Roman London. Antiquity, **64**, 620–628.

Ms. ricevuto il 2 agosto 2010
Testo definitivo ricevuto il 16 ottobre 2010

Ms. received: August 2, 2010
Final text received: October 16, 2010