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SHAPE RECONSTRUCTION OF THE PLEISTOCENE/HOLOCENE UNCONFORMITY IN THE GROSSETO ALLUVIAL PLAIN (TUSCANY, ITALY)

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ABSTRACT: Biserni G., Berendsen J.A.H. and Sandrelli F., *Shape reconstruction of the Pleistocene/Holocene unconformity in the Grosseto alluvial plain (Tuscany, Italy)* (IT ISSN 0394-3356, 2004)
One hundred two boreholes were drilled in Grosseto alluvial plain (Tuscany, Italy). Coring evidence shows a sharp lithological change that is interpreted as a Pleistocene/Holocene unconformity. This suggests the presence of a paleovalley that was eroded by the Ombrone river during the last glacial interval. Radiocarbon samples and surface's geometry of lithological changes corroborate this explanation.

RIASSUNTO : Biserni G., Berendsen J.A.H. and Sandrelli F., Ricostruzione dell'andamento della unconformity pleistocenica-olocenica all'interno della pianura alluvionale grossetana (Toscana, Italia) *(IT ISSN 0394-3356, 2004)*
La pianura di Grosseto, all'interno della quale scorrono il Fiume Bruna e Ombrone, si estende per circa 370 Km² ed è delimitata dai rilievi di Castiglione della Pescaia a Nord-Est, dalle colline di Grosseto ad Est e dai Monti dell'Uccellina a Sud (Fig.1). Bravetti & Pranzini (1987), Innocenti & Pranzini (1993), Stea (1995), Bellotti et al*., (1999), Bellotti* et al*., (2001) e Carboni* et al*., (2002) ricostruiscono la lenta evoluzione di questa pianura durante il Quaternario. La caduta del livello marino, venutosi a verificare durante l'ultimo glaciale (Stadio 5e), determinò un abbassamento del livello di base di circa 120 m. I Fiumi Ombrone e Bruna scavarono due paleovalli nelle precedenti alluvioni presso i lati della pianura attuale, lasciando in rilievo la parte mediana. La successiva trasgressione versiliana trasformò le due valli in insenature marine in seguito colmate, con velocità diverse dai due fiumi.*
In questo lavoro, mediante una serie (circa 100) di microperforazioni manuali e alcune perforazioni profonde, viene ricostruito l'andamento di una unconformity *all'interno della pianura alluvionale grossetana, interpretata, grazie a datazioni radiometriche, come pleistocenica-olocenica. La sua forma suggerisce la presenza di una paleovalle erosa dal Fiume Ombrone durante l'ultima glaciazione.*

Keywords : Pleistocene/Holocene unconformity; paleovalley, radiocarbon dating.

Parole chiave : unconformity pleistocenica-olocenica,; paleovalle, datazioni radiometriche.

INTRODUCTION

The Grosseto plain is delimited by the Castiglione della Pescaia Hills in the northwest, Grosseto Hills in the east, and Uccellina Mounts in the south (Fig. 1). The sedimentary evolution of the Grosseto plain during the Quaternary was previously described based on stratigraphies derived from wells drilled randomly by farmers and with subsurface data collected for a hydrogeologic study (Bravetti & Pranzini, 1987; Bellotti *et al*., 1999).

During the Late Pleistocene, fluvial and aeolian sediments were deposited, which now crop out in low terraces along the borders of the alluvial plain (Mazzanti, 1983; Bravetti & Pranzini, 1987). During the last glacial interval, when sea level dropped approximately 100 m below the present level, the Ombrone and Bruna Rivers presumably cut two valleys into Pleistocene deposits, on opposite sides of the present alluvial plain. The valleys became sedimentary areas for marine and river deposits during the Holocene transgression (Versilian transgression). The southern valley was filled more rapidly because the Ombrone River carries more clastic material than the Bruna River.

So far, the thickness of the Holocene sediments has not been determined in a reliable way, and evidence for the existence of these paleovalleys was not presented so far. Data from Stea (1995) and Bellotti *et al.* (2001, 2004) suggest a Holocene thickness of up to 50 m. However, the dates of Bellotti *et al*. (2001, 2004) do not agree with the sea level curve for the Tyrrhenian Sea (Biserni *et al.*, submitted). If the dates of Bellotti et al. (2001) are plotted on the Tyrrhenian sea level curve (Biserni, 2004), it can be seen that their data deviate considerably from the curve, suggesting that their data are not coherent with the Tyrrhenian environmental evolution during the Holocene. Cause of that these data cannot be used to calculate reliable sedimentation rates. A possible reason for this deviation is that the borehole of Bellotti et al. (2001) was drilled in the channel belt of the river. This inevitably leads to an overestimation of sedimentation rates, because channels incise into the Pleistocene substratum. Berendsen (1982), Törnqvist (1993) and Makaske (1998) suggested to collect samples within the alluvial plain to reliably measure sedimentation rates.

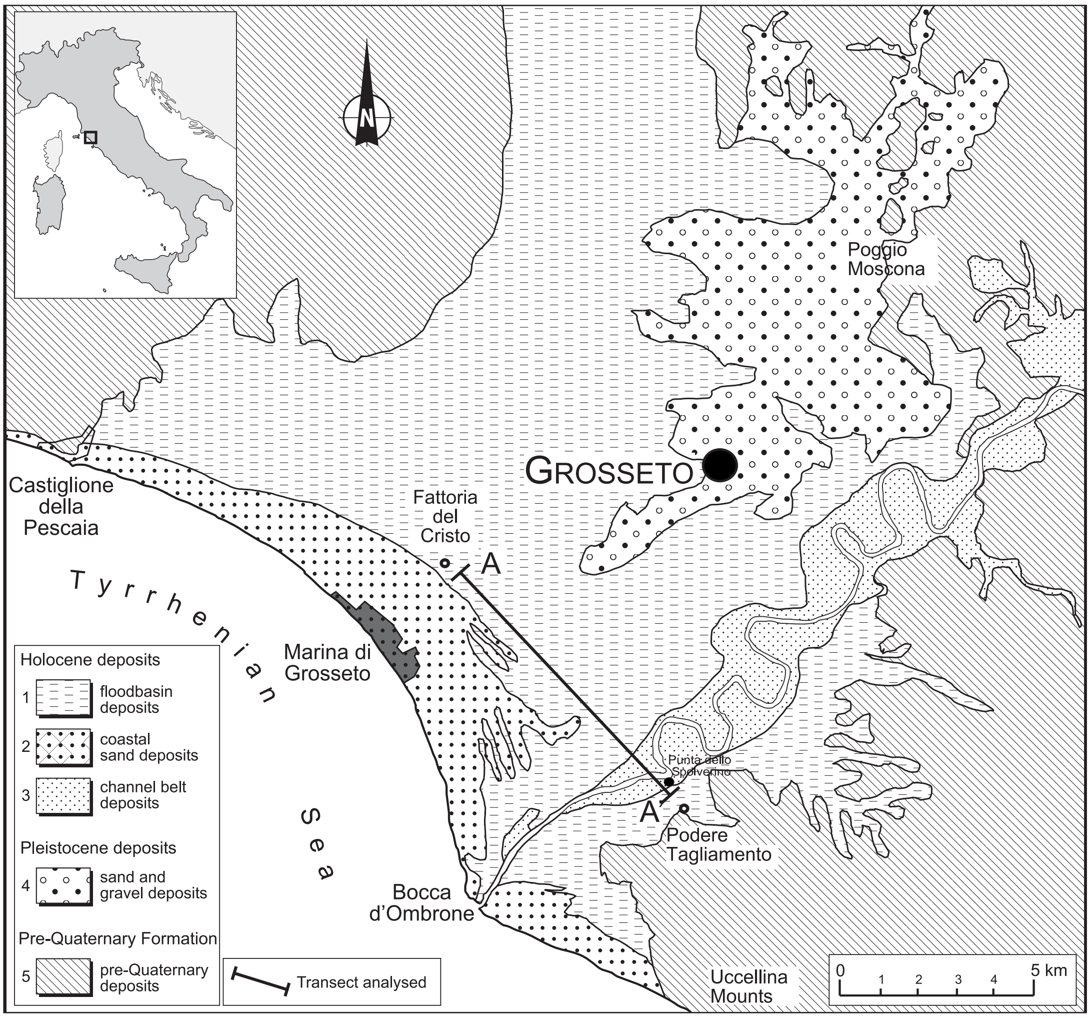

Fig. 1 - Geological sketch map of the Ombrone River basin (after Geological Map of Italy, simplified).
Carta geologica schematica della parte terminale del bacino del Fiume Ombrone (Carta Geologica dell'Italia, semplificata).

The purpose of this study was to approximately determine the thickness of the Holocene sediments and to reconstruct the shape of the Late-Pleistocene Ombrone paleovalley that was incised during sea level low stand.

METHODS

We performed a geomorphological and lithostratigraphical study and radiocarbon dated organic deposits in the Ombrone plain. This has been done by drilling a series of boreholes and by analyzing deep mechanical wells drilled by farmers. Three radiocarbon samples were obtained for time control.

Coring and alluvial architecture

The lithological information was obtained by coring, as there were no outcrops available. Boreholes were drilled in a ~ 6 km long section in a NW-SE direction. Whenever possible, boreholes were drilled at 50 m intervals. The cores reached an average depth of 8-9 m, the deepest one is 15 m and the shallowest one is 4 m. The transect is situated approximately 6 km from the coast and crosses the Ombrone River in Punta dello Spolverino (Fig. 1). The cores reached an average depth of 8-9 m. We used a gouge and piston corer to study the stratigraphy and to collect samples for Accelerator Mass Spectometry (AMS) radiocarbon dating. All sediment cores were described in the field at 10 cm intervals with regard to texture, organic content, color, median grain size of sand (using a sand ruler), gravel content, oxydized iron content, calcium carbonate content (using a 5 % HCl solution), occurrence of groundwater, shells and other characteristics, following Berendsen & Stouthamer (2001). The lithologic units were subsequently grouped into 'lithogenic units' of 'facies units', an approach that closely follows Berendsen (1982) and Miall (1985). The structure of facies units in a delta complex is generally called alluvial architecture. Each unit is characterized by its grain size, composition, internal sequence and external geometry.

Loss On Ignition (LOI) analyses were carried out on samples from borehole 58.

Three typical architectural elements occurring in a

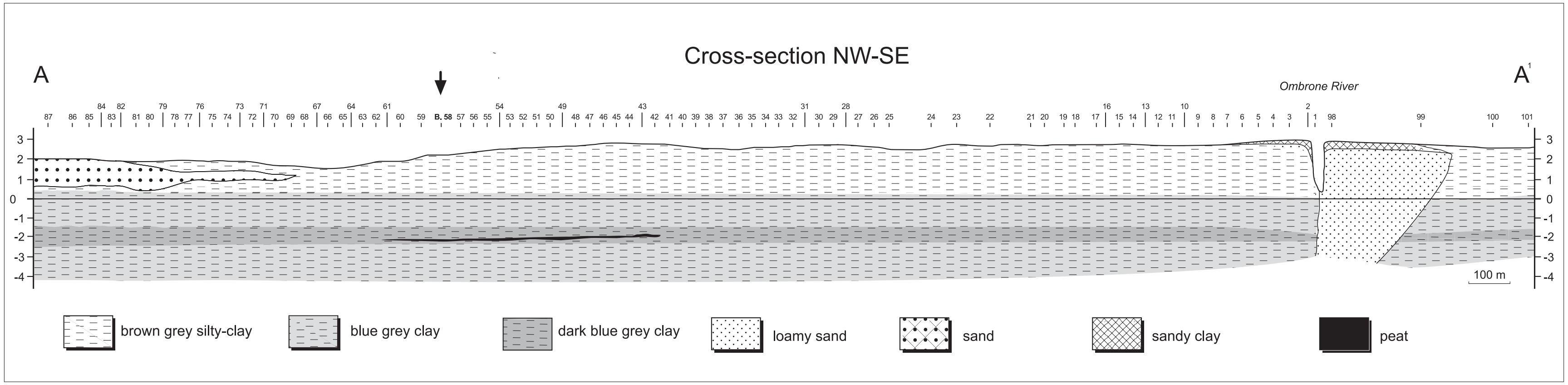

Fig. 2a - Lithology of transect A-A
Ricostruzione litologica del transetto A-A

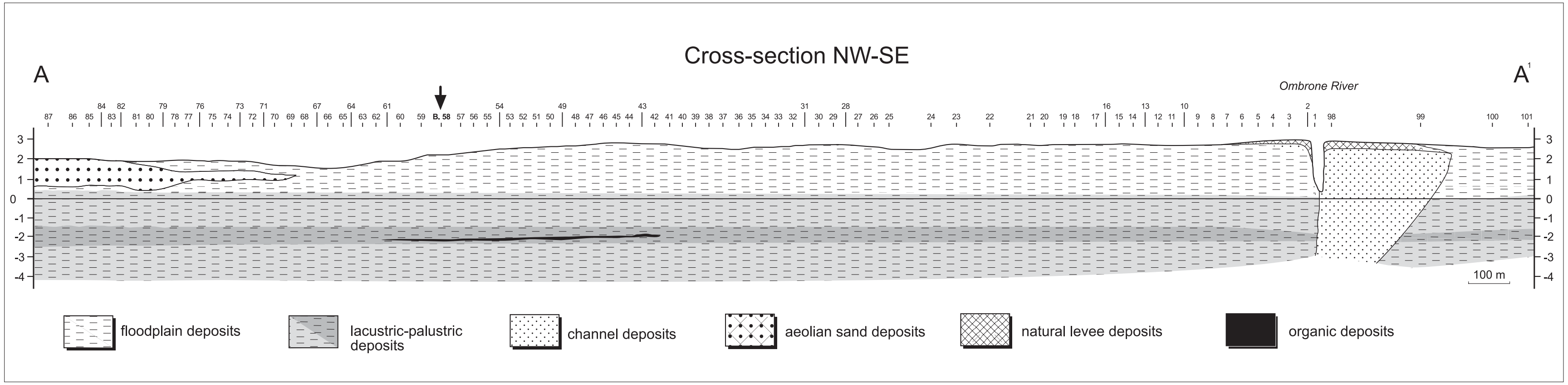

Fig. 2b - Architectural elements of transect A-A
Elementi architetturali del transetto A-A

Figure 2 -Cross section through A-A in the Ombrone River. The lithology is interpreted in terms of architectural elements. For location see Fig. 1
Sezione litologica del bacino del Fiume Ombrone e interpretazione geologica in termini di elementi dell'architettura fluviale

meandering alluvial plain were recognized:

- Small natural levee deposits, consisting of sandy clay. The wedge-shaped natural levees occur near the Ombrone River.
- Channel deposits, consisting of sand, deposited by the Ombrone River. The channel deposits are ribbon-shaped sandbodies.
- Floodplain deposits, consisting of gray-brown silty-clay that overlies dark gray blue lacustric clay. Thin layers of organic material (*peat*) occur intercalated in the floodbasin deposits.

The alluvial architecture of the Ombrone area is shown in Figure 2.

Two organic samples were selected for Accelerator Mass Spectrometry (AMS) radiocarbon dating using terrestrial macrofossils.

Laser diffraction analysis

Soil samples were collected randomly all over the alluvial plain, between 50 and 80 cm below the surface. In the low lying part of the alluvial plain, the upper 40-50 cm are thought to be a result of reclamations (La bonifica grossetana, 1956), hence no samples were taken from the upper 50 cm. All samples were taken using an Edelman hand auger. Grain size of these samples was studied using laser diffraction analysis.

Results of the laser diffraction analyses are shown in a soil map of the alluvial plain presented in Figure 4.

Geomorphological-geological mapping

In mapping the Ombrone fluvial system, borehole descriptions were interpreted following the approach of Berendsen (1982), Miall (1985) and Berendsen & Stouthamer (2001). The main features of the Ombrone River and the Grosseto alluvial plain have been analyzed from a morphological and sedimentological viewpoint, using maps, aerial photographs and field evidence. Four morphological elements are shown in Figure 3:

➢ a beach-ridge delta plain parallel to the coastline, characterized by a wide dune-belt close to the present river mouth, that becomes narrow near Castiglione della Pescaia, where high foredunes occur (Mori, 1935; Bird & Jones, 1988);

➢ a wide, fairly flat and low-lying floodplain located behind the beach-ridge. The floodplain is higher near the channel belt, reaching an elevation of 3-4 m above sealevel;

➢ an approximately 1 km wide channel belt of the Ombrone River.

➢ a higher elevated area can be distinguished in the middle-Eastern part of the alluvial plain. A scarp of 3-4 m occurs near to “Il Poggiale”, “Le Gorarelle” and “La Rugginosa”, SW, S and ENE of Grosseto. Elevation increases from 5-6 meters to 15-19 m close to the Istia Hills.

RESULTS

Lithostratigraphy

Borehole Ombrone 58 (see Fig. 2), can be regarded as representative for the Ombrone alluvial plain, and will be described here in more detail. The lithology has been studied through accurate field and laboratory inspection. The core was divided in 8 lithozones (Fig. 5) reflecting varying environmental conditions.

The sediments of *lithozone* a indicate a sporadic high-energy environment in a generally low energy setting, dominated by clay sedimentation. The presence of sand layers and broken and complete marine shells (like *Cerastoderma* sp., *Hydrobia* sp., *Tellinea pulchella*) in a clayey matrix suggests marine flooding. From this layer, at a depth of 8.76 m below the surface, a sample was taken for radiocarbon analyses, which yielded a radiocarbon age of 7724-7651 cal yr BP.

The smaller grain size of the overlying lithozone (***b***) indicates a general decrease of energy. The fine grain size and the presence of a thin peaty horizon in *lithozone c* indicates a low-energy environment no longer affected by floods and storms.

Lithozones d and e are characterized by slightly organic gray-blue clay; the organic content in *lithozone e* decreases upward.

Lithozones (*f-h*) are characterized by lithological change, from blue clay to gray-brown silty clay, to gray-brown clayey silt characterized by an upwards decreasing organic content and a gradual increase of oxidation coatings. Those characteristics indicate an alluvial environment connected with the Ombrone River. A change of grain size, the occurrence of reworked fossils

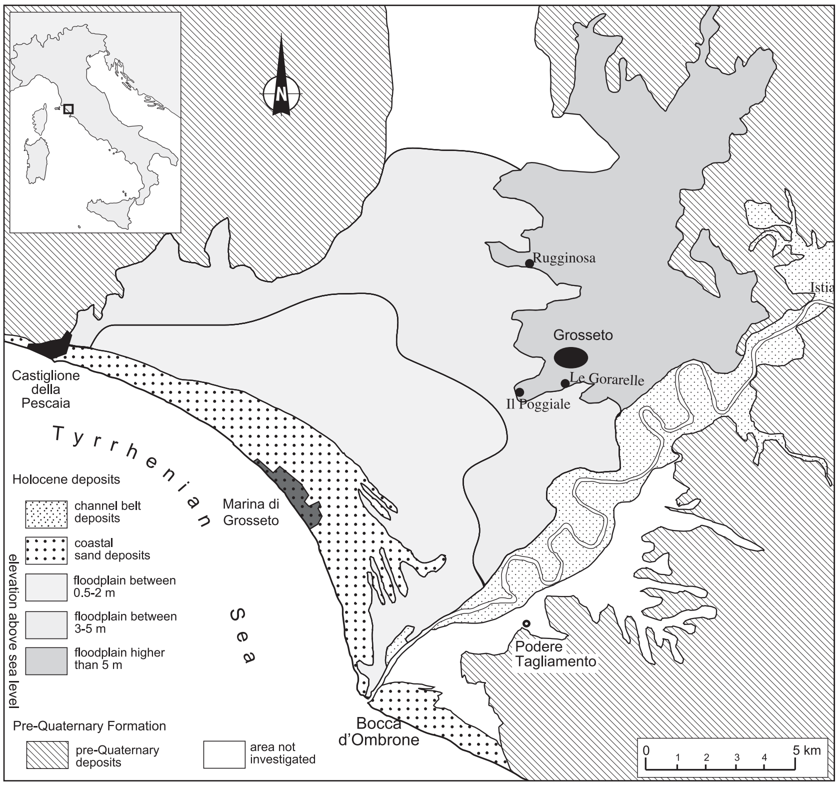

Fig. 3 - Morphological and sedimentological sketch map of the Grosseto alluvial plain
Carta morfologica e sedimentologica della pianura alluvionale grossetana

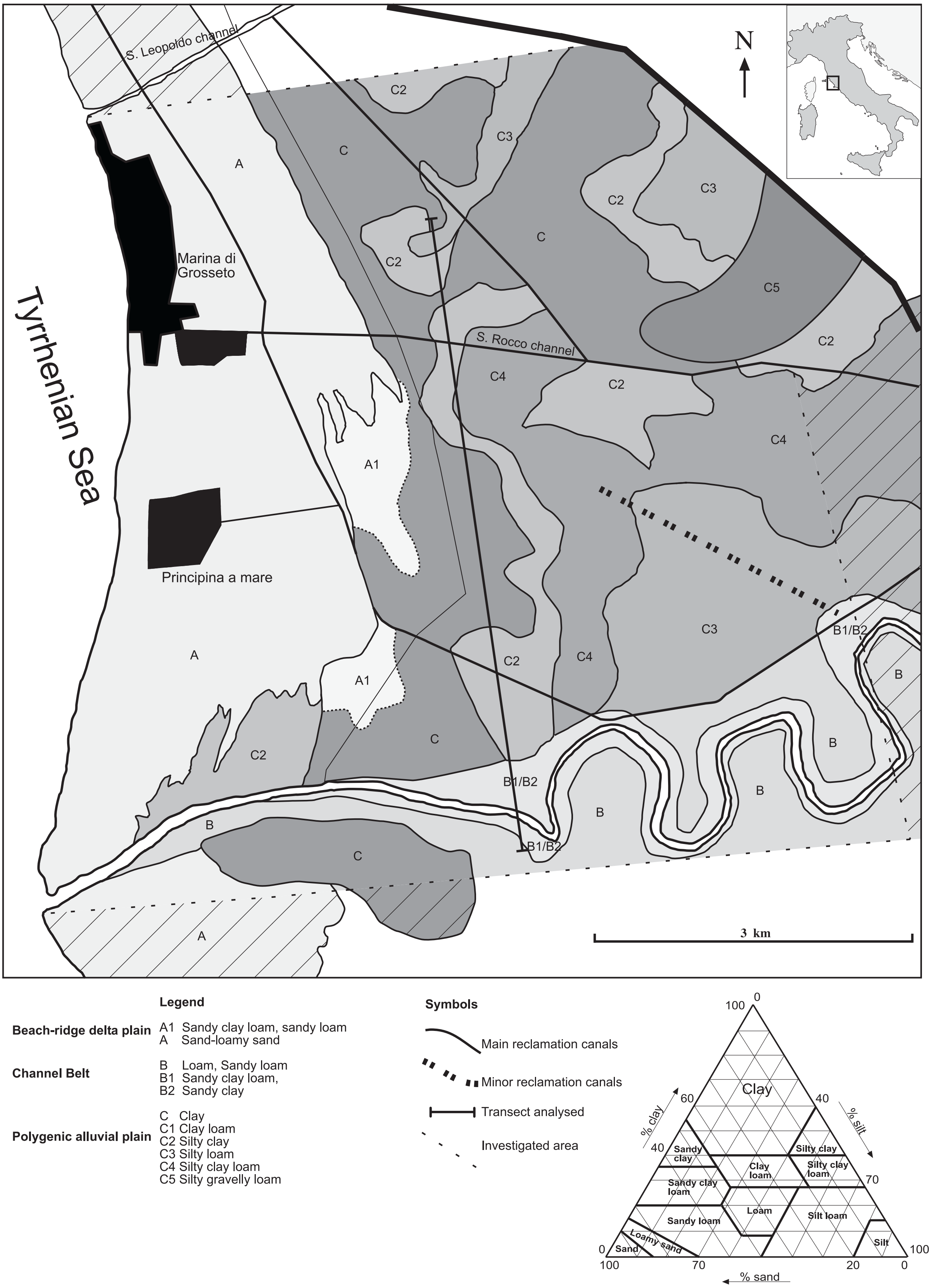

Fig. 4 - Soil map of the Ombrone alluvial plain (after Sevink *et al*., 1982; modified)
Carta dei suoli della pianura alluvionale del Fiume Ombrone (Sevink et al*., 1982; modificata)*

Lithozone h: -80 cm to the top of borehole: brown clayey silt soil with fine gravels, influenced by agricultural activity.

Lithozone g: -140 to -80 cm: grey brown clayey silt, characterised by a high Ca content and oxidation coatings.

Lithozone f: -240 to -140 cm: grey brown silty clay, characterised by high Ca content and oxidation coatings.

Lithozone e: -300 to -240 cm: grey clay with, especially upwards, oxidation coatings.

Lithozone d: -400 to -300 cm: grey blue clay characterised by low organic content.

Lithozone c: -450 to -400 cm: grey blue-dark organic clay. This lithozone is characterised by a medium-high organic content. Thin peat layer occurs. Evidences of anoxic environments occur.

Lithozone b: -650 to -450 cm: grey blue clay sporadically characterised by small layers of dark grey organic clay, a few centimetres thick. The sediment is plastic and marine shells (broken and complete molluscs) occur randomly.

Lithozone a: -880 to -650 cm: grey blue clay characterized by gray layers of loose medium sand, a few centimetres thick, and by broken and complete marine shell layers occurring at 30 to 40 cm intervals. Upwards the sandy layers and

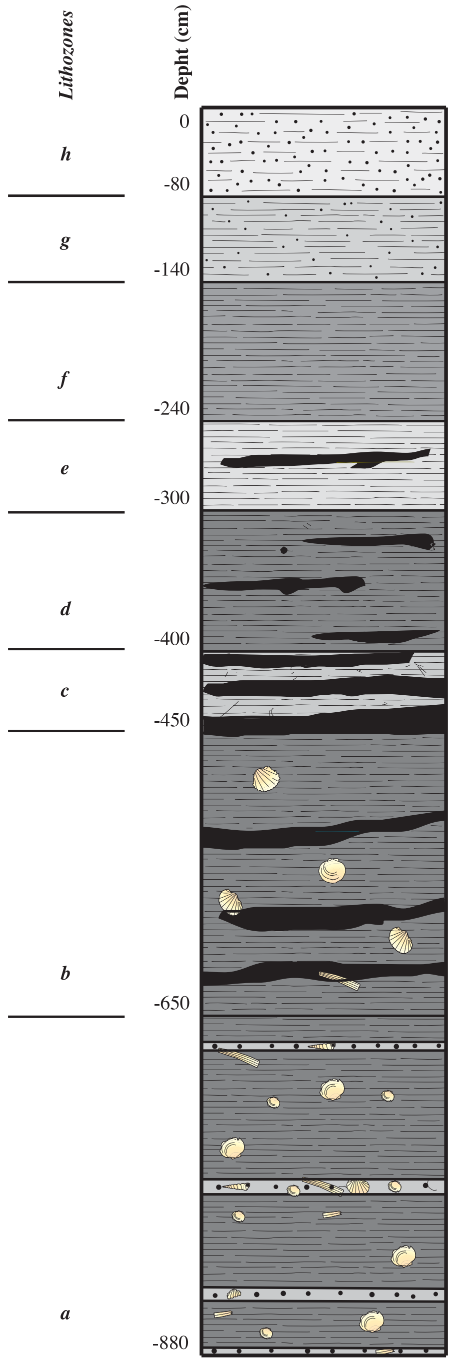

Fig. 5 - Lithological log of Borehole 58 (depth in cm below ground level)

Ricostruzione litologica dei sedimenti rinvenuti dal Borehole 58 (la profondità è espressa in cm)

and the presence of Glomus indicates a supply of sediments from the river. The uppermost part of the lithological log is affected by pedogenesis and agriculture.

Evidence for a stratigraphic unconformity

Approximately 15 new wells mechanically-drilled were accurately examined, in addition to one borehole obtained by Bellotti *et al*. (2001). The stratigraphies of the wells in the lower part of the alluvial plain (Table 1) are characterized by an alternation of aquatic gray-blue clay and dark-blue or gray clay with a varying micro- and macrofossil content in the upper 11-12 m (Biserni *et al*., 2001), very similar to the sediments of borehole B-58 described above. A sudden and sharp change of sedimentary facies from gray-blue clay and dark-blue or gray clay to brown-yellow-beige clay-silt characterized by oxydation coatings occurs in the Ponte Nuovo and Casotto dei Pescatori wells at a depth of approximately 9-10 m and 11-12 m below the surface respectively.

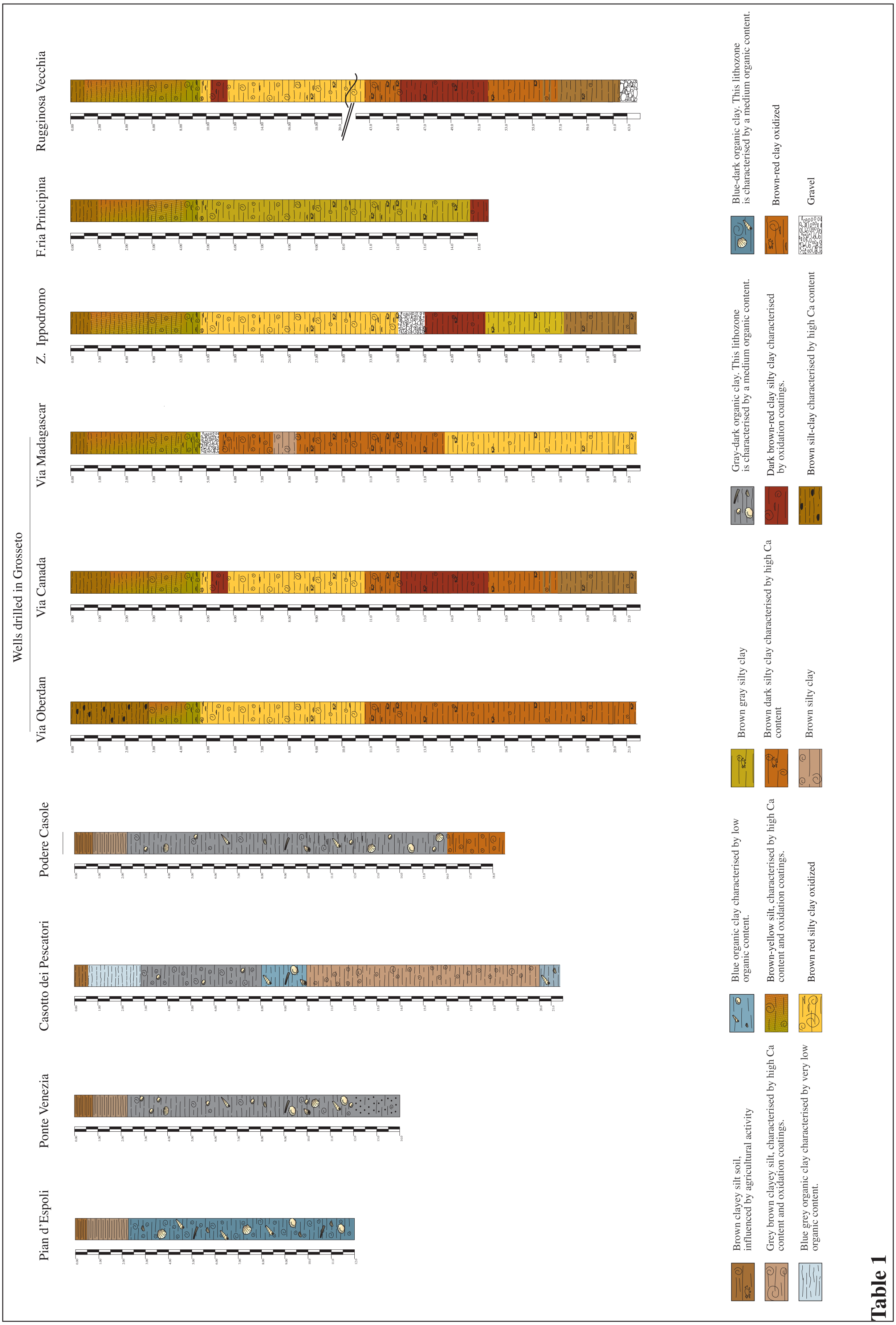
Wells drilled in Grosseto
Pian d'Espoli
Ponte Venezia
Casotto dei Pescatori
Podere Casole
Via Oberdan
Via Canada
Via Madagascar
Z. Ippodromo
F.ria Principina
Rugginosa Vecchia
Brown clayey silt soil, influenced by agricultural activity
Grey brown clayey silt, characterised by high Ca content and oxidation coatings.
Blue grey organic clay characterised by very low organic content.
Blue organic clay characterised by low organic content.
Brown-yellow silt, characterised by high Ca content and oxidation coatings.
Brown red silty clay oxidized
Brown gray silty clay
Brown dark silty clay characterised by high Ca content
Brown silty clay
Gray-dark organic clay. This lithozone is characterised by a medium organic content.
Dark brown-red clay silty clay characterised by oxidation coatings.
Brown silt-clay characterised by high Ca content
Blue-dark organic clay. This lithozone is characterised by a medium organic content.
Brown-red clay oxidized
Gravel

Table 1

Wells drilled in the elevated part of the alluvial plain (e.g. Fattoria la Principina, Rugginosa, via Canada, via Madagascar and via Oberdan, see Table 1) show the same brown-yellow-beige clay-silt from the surface on downwards. Samples collected from this depth for paleobotanical and paleontological analyses are extremely poor in macrofossils, and pollen grains, if present, are not well preserved (e.g. in samples from a depth of 4.0, 4.5, 5.0, 5.5 ,7.0 and 7.5 m below the surface in well Casotto dei Pescatori). These sediments seem to have formed under subaerial conditions.

The same lithological and paleobotanical transition occurs at a depth of approximately 16-17 m below the surface in boreholes P. Casole and P. Isonzo that are located close to the river.

In Figure 6 the subsurface elevation of the transition is plotted in section 1,2 and 3. The geometry of the transition suggests the presence of a paleovalley below the present Ombrone river, that may have formed during the last sealevel lowstand (Bravetti & Pranzini, 1987).

New AMS data, here presented, give a new contribution to reconstruct the development of this area during the transition between Pleistocene and Holocene. A sample for AMS radiocarbon dating was collected from well Casotto dei Pescatori at a depth of 22 m below the surface. This sample yielded an age of 36400 ± 2800 yr BP. In borehole 58 a radiocarbon sample from a depth of 8.76 m was dated at 6860 +/- 50 yr BP. These AMS date, lithological observation and the surface's geometry of lithological changes described above and reconstructed in Fig. 6 point out that the lithological transition may represent an unconformity, which represents the Pleistocene/Holocene boundary.

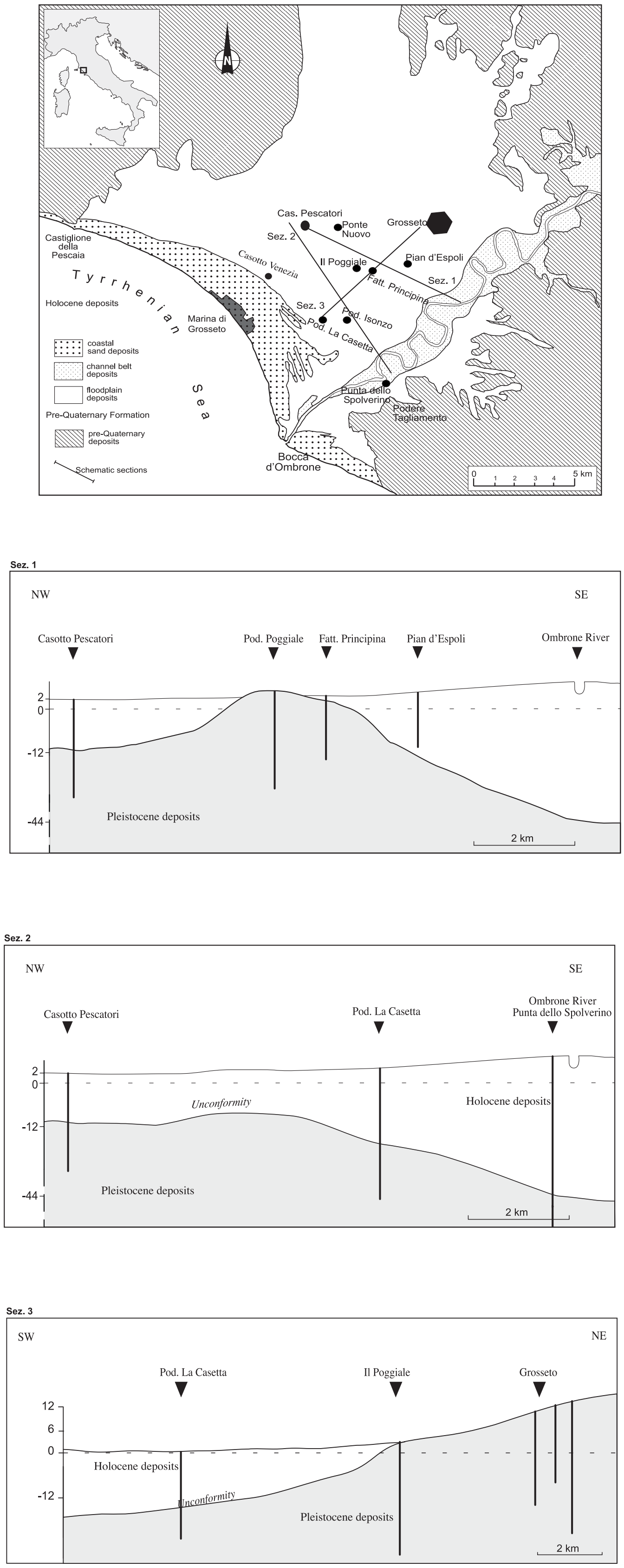

Fig. 6 - Schematic sections through the Grosseto alluvial plain
Sezioni schematiche attraverso la pianura alluvionale grossetana

CONCLUSIONS

The higher part of the Grosseto alluvial plain is lithologically and morphologically different from the low alluvial plain. It is delimited by a scarp of 3-4 m. The higher part is interpreted as a terrace, originally separating two palaeovalleys incised during the last glacial (*MIS 2-4*) (Mazzanti, 1983; Bravetti & Pranzini, 1987; Bellotti *et al*., 2001). Based on lithological and micropaleontological similarities, the surface of the terrace is correlated with the sediments that occur in boreholes below the sharp lithological change. Therefore the lithological transition in the boreholes is interpreted to respresent an unconformity at the Pleistocene/Holocene transition. Radiocarbon ages corroborate this interpretation. The paleovalley most likely formed by incision during the lowstand of the Tyrrhenian Sea.

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