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GEOMORPHOLOGICAL CHANGES DUE TO HUMAN ACTIONS AT COPPA NEVIGATA (TAVOLIERE DI PUGLIA, SOUTHERN ITALY) RECONSTRUCTED THROUGH CORE ANALYSES

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ABSTRACT: M. Caldara et al., *Geomorphological changes due to human actions at Coppa Nevigata (Tavoliere di Puglia, southern Italy) reconstructed through core analyses*. IT ISSN 0394-3356, 2004
The area surrounding the Coppa Nevigata settlement is one of the best places for the reconstruction of the relationship between human activities and the environment since the first Tavoliere di Puglia population phases. The settlement is the best studied in the Tavoliere plain, it is situated between the foot of the Gargano headland and the inner shore of the ancient Salpi lagoon, in a very sensitive area from the environmental point of view. Previous studies highlighted the environment evolution and its chronology. The close relationship between the wet area facing the settlement and the population pattern in some cases was documented. The preliminary study of six new cores and considerations made on three previously drilled successions are the base of this research. The studied successions were grouped in three transects and described in function of their distance from the settlement. These are the **A** (distal), **B** (in the middle) and the **C** (proximal) transects. There were recognized eight different phases attributable to two different evolutionary patterns. The environments set under or modified by intentional anthropic action, such as the **B** (terrestrial phase I), **D** (terrestrial phase II) and **H** (historical reclamation) phases, have to be ascribed to the first one. The almost "natural" phases belong to the second one, even if the accumulated material is often related to human actions. These are the phases **A** (natural phase I), **C** (natural phase II), **E** (natural phase III), **F** (arid terrestrial phase) and **G** (natural phase IV). The **B** and **D** anthropic phases have been recognized beneath the ground surface up to about 90 m far from the nearest exploration ditches dug by archaeologists on the side of the Coppa Nevigata knoll. We were not able to put a boundary between these two phases within the **C** transect cores, but they are well defined in the **A** transect. The anthropic phase **B** corresponds to an urbanization phase that seems to have been started from the most internal settlement areas through the artificial compaction/leveling of marshy/lagoonal deposits, whereas the presence of hearths in distal areas could be attributed to activities carried out outside the defensive wall system. The anthropogenic **D** phase shows, in the area next to the hillock side, the presence of simple inhabitation structures that lasted for a relatively long time, as testified by numerous tramped and/or leveled surfaces (simple or superimposed) associated to concotto levels and hearths. On the other hand in distal areas the **D** phase seems to be characterized by an agricultural/pastoral land use. The **H** phase sediments have locally accumulated under nearly natural conditions, even if they are directly related to reclamation works made during the last two centuries. In conclusion, through time man modified and shaped the environment around the Coppa Nevigata knoll, in particular during the Middle Bronze age (**B** phase), the Iron age (**D** phase) and during the last two centuries (**H** phase). Sometimes the sedimentation processes under natural conditions were also strongly influenced by man, as suggested by the presence of the organic deposits accumulated during the **A** phase or by the **C** phase sediments.

RIASSUNTO: M. Caldara et al., Variazioni dell'ambiente geomorfologico indotte dall'Uomo desunte dallo studio di carotaggi a Coppa Nevigata (Tavoliere di Puglia)*. IT ISSN 0394-3356, 2004*
*L'area a ridosso dell'insediamento preistorico di Coppa Nevigata è quella che meglio si presta per la ricostruzione dei rapporti intercorsi tra l'Uomo e l'ambiente a partire dalle prime fasi di popolamento del Tavoliere di Puglia. Difatti, questo insediamento è certo quello più studiato del Tavoliere ed inoltre era collocato ai piedi del Promontorio del Gargano sul margine interno dell'antica laguna di Salpi, in un'area ad alta sensibilità ambientale, in quanto soggetta alle rapide modificazioni dovute alla combinazione di processi diversi (fluviale, marino, eolico ecc.) e all'opera dell'Uomo. Studi precedenti degli Autori hanno delineato l'evoluzione degli ambienti e la loro collocazione cronologica. Inoltre, in alcuni casi hanno messo in evidenza la stretta correlazione fra l'area umida antistante l'abitato di Coppa Nevigata e le modalità di vita e di sviluppo dell'insediamento. Lo studio preliminare di sei nuove perforazioni, realizzate ad hoc a ridosso della collina di Coppa Nevigata, unito ad altre tre fatte precedentemente, è alla base del presente lavoro. Le successioni sono state riunite in tre gruppi e descritte in funzione della loro distanza dall'insediamento (transetto **A**, distale; transetto **B**, intermedio e transetto **C**, a ridosso della collina di Coppa Nevigata). Sono state riconosciute otto diverse fasi riconducibili grosso modo a due differenti modelli evolutivi. Al primo appartengono gli ambienti originatisi o rimodellati intenzionalmente dall'Uomo: fasi **B** (fase continentale I), **D** (fase continentale II), e **H** (colmate storiche). Al secondo appartengono gli ambienti dove il meccanismo di accumulo dei sedimenti è naturale, anche se molte volte i materiali accumulatisi sono riconducibili alle attività dell'Uomo: fasi **A** (fase naturale I), **C** (fase naturale II), **E** (fase naturale III), **F** (fase continentale arida) e **G** (fase naturale IV). Le fasi antropiche **B** e **D** che non si riescono a differenziare nelle successioni del gruppo **C**, quelle a ridosso dell'insediamento, e che sono ben separate nelle successioni del gruppo **A**, si ritrovano fino a circa 90 metri dai più vicini saggi archeologici. La fase antropica **B** corrisponde ad una fase di urbanizzazione che sembra procedere a partire dalle aree più prossime all'insediamento compattando i depositi palustri e/o lagunari con battuti, mentre nelle aree più lontane l'attività, limitata a soli focolari, sembra quella svolta all'esterno delle mura. La fase antropica **D** mostra, nell'area a ridosso della collina di Coppa Nevigata, la presenza, più o meno continua nel tempo, di strutture abitative semplici (abbondanza di battuti singoli e/o sovrapposti uniti a livelli di concotto e a focolari), mentre per le aree distali mostra una utilizzazione di tipo agricolo-pastorale. La fase antropica **H** è riconducibile alle colmate storiche degli ultimi secoli. Si tratta di un deposito realizzato con intenzionalità dall'Uomo anche se i meccanismi di sedimentazione sono praticamente naturali. In definitiva nell'area di Coppa Nevigata l'Uomo ha rimodellato e modificato il paesaggio più volte, durante il Bronzo medio (fase **B**), l'età del Ferro (fase **D**) e negli ultimi due secoli (fase **H**). Comunque è stato fortemente attivo condizionando la sedimentazione anche nella fase **A** con depositi organici, e nella fase **C**.*

Keywords: buried morphology, geoarchaeology, Tavoliere di Puglia, Holocene.

Parole chiave: morfologie sepolte, geoarcheologia, Tavoliere di Puglia, Olocene.

1. INTRODUCTION

The Coppa Nevigata settlement is one of the best known archaeological sites in the Apulian region. It is located at 41°33'26"N, 15°50'00"E, some five kilometres from the modern coast, between the Gargano Promontory and the Tavoliere Plain. The site was situated on the inner shore of the Holocene Salpi lagoon (Boenzi *et al*., 2001), a coastal waterbody extended from south of Manfredonia to the Ofanto river delta and now totally disappeared because of both natural infilling and land reclamation works (Boenzi *et al*., in press; Caldara *et al*., 2002b).

The archaeological site is known since the first years of the XX century (Mosso, 1909). Nevertheless, it was subjected to systematic archaeological explorations only from the '50s of last century (Puglisi, 1955; 1975; 1982). The investigations started again in 1983 with extensive excavations still in progress (Cazzella & Moscoloni, 1988; 1990; Cazzella *et al*., 2001). The archaeological research evidenced a complex stratigraphy spanning from the Early Neolithic, throughout the Bronze age and into the Iron age (Cazzella, 1996; Cazzella & Moscoloni, 1999). During the various inhabitation phases the mode of occupation changed (Caldara *et al*., 2003a).

Since the '90s the Authors have been investigating the coastal plain of the Tavoliere, but the choice to focalise the multidisciplinary efforts in a sample area occurred only later. The Coppa Nevigata settlement offered good research possibilities, since the good knowledge acquired through decades of archaeological study as well as its location in a high sensitive environmental frame. The best available information suggests that the population around the lagoonal area increased and decreased several times. One explanation of this is past changes in the regional environmental conditions (Boenzi *et al*., 2001; Caldara *et al*., 2002b).

In 1997 five cores were drilled (CN1 to CN5) at various distances from the settlement (Fig. 1). The

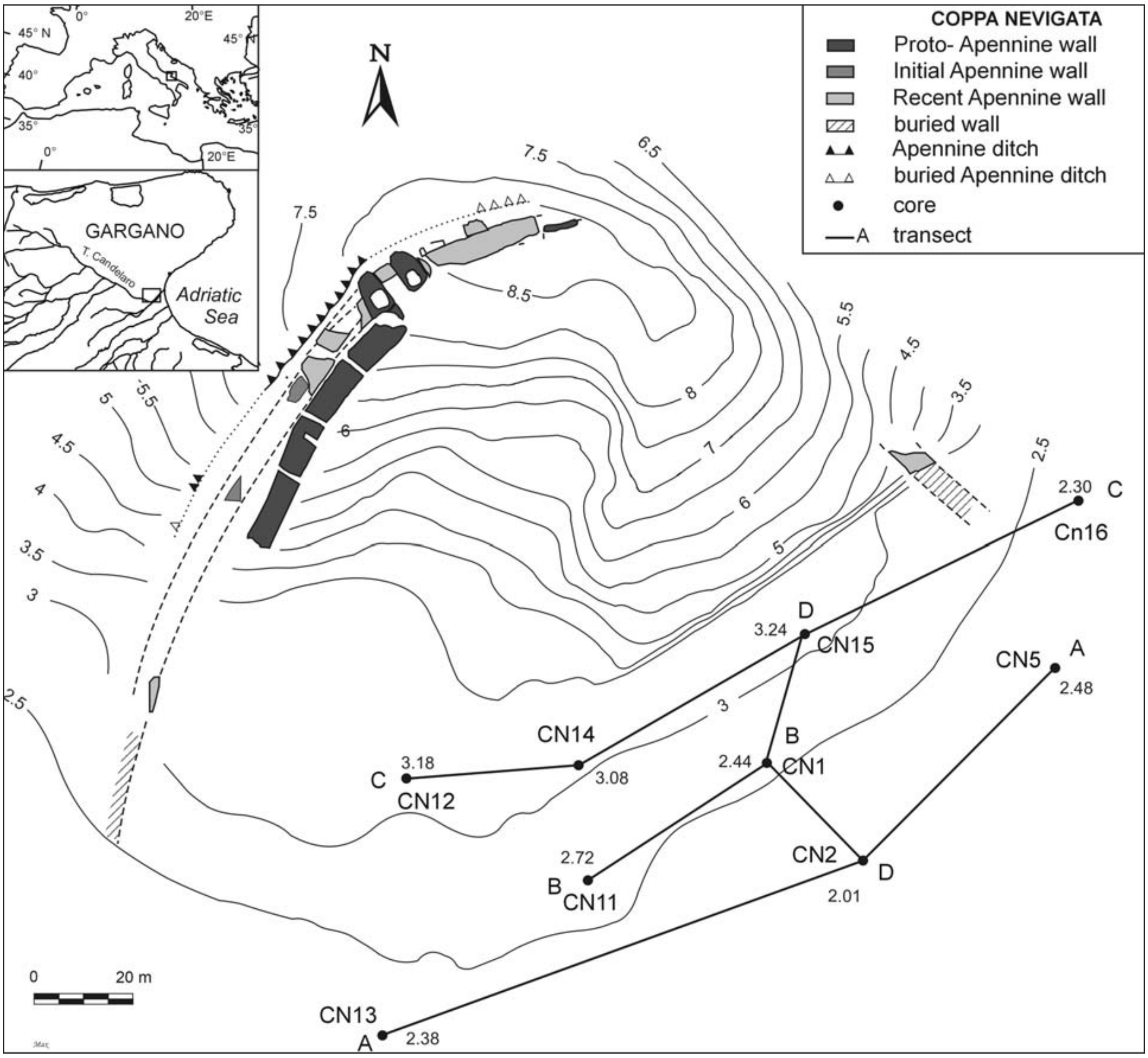

Fig. 1 - Location of the studied areas. CNn = coring site.
Ubicazione dell'area. CNn = posizione dei sondaggi.

study of two of the nearest cores to the site (CN2 and CN5) is by now complete (Caldara *et al.* 1999; 2001; 2003b; in press c), while the most distant ones (CN3 and CN4) are still under examination (Simone 2003; Caldara *et al*., in press c). The first results obtained were the reconstruction of the environment evolution close to the site (Caldara *et al*., 1999; 2001) and the understanding of chronology of the events (Caldara *et al*., 2003a).

The idea at the base of our research were that there was a close relationship between the wet area facing the Coppa Nevigata knoll and the way in which the settlement developed (Caldara *et al*., 2002a). This connection has been documented in various cases. As an example, at the site were found ceramic artifacts, dating back between the Proto-Apennine and the Sub-Apennine periods, containing tephra (Levi *et al.* 1999). The use of pyroclastic material as a tempering ingredient to make ceramics was possible by the presence of this kind of sediments in the lagoon bottom (Caldara *et al*., 2001). An other example is the use of the cockle *Cerastoderma glaucum* as a food resource, in particular during the Neolithic and the Bronze age (Late Sub-Apennine), as documented by Minniti (1999).

As the study progressed we realized that, especially during the Middle Bronze age, man influenced the local environment evolution (Caldara & Simone 2003; in press), as attested by the presence of deposits directly related to anthropogenic activities only within the cores nearest to the settlement.

The aim of this research is to asses how strong was the impact of human actions on the surrounding environment. One of the possible ways to reach this goal was the detailed reconstruction of the geometries of buried sedimentary bodies (both of natural and anthropic origin). To verify our hypotheses, six new cores were drilled in 2002 (CN11 to CN16). The coring locations were accurately decided on a detailed map (Fig. 1), in order to get a good distribution of samples. Thus, at the base of this paper are the preliminary results of the study of the six new cores plus the CN1, compared and integrated with data obtained by the analysis of CN2 and CN5 successions.

2. GEOLOGICAL AND MORPHOLOGICAL SETTING

The Coppa Nevigata knoll is situated along the south-east transition area (Fig. 2) between the smooth limestone surface of the southern Gargano terraces area, called "Pedegargano" by Caldara & Palmentola (1991), and the alluvial coastal plain of the Tavoliere di Puglia (Southern Italy).

The Gargano is a calcareous massif, part of the Mesozoic Apulia Platform. The outcropping rocks in the southern area of the headland are the oolithic, pseudo-oolithic, detritic and micritic limestone of the Portlandian, "Calcari oolitici di Coppa Guardiola" Formation (Luperto Sinni & Masse, 1986). In particular, the lower terrace at the foot of the headland, dips gently eastward starting from elevations slightly above 100 meters a.s.l.. The sub-horizontal surface, in correspondence of the terminal section of the Candelaro stream, has been divided in several minor block by NW-SE faults.

The Tavoliere plain subsoil is made of a thick succession of Quaternary terrigenous sediments overlaying the Bradanic Cycle deposits, in particular the "Argille subappennine" Formation. Starting from the end of the Lower Pleistocene, due to some stands of the regional uplift combined with glacio-eustatic movements, the Tavoliere landscape was shaped in a number of marine terraces gently sloping down towards the sea. Some of them are now covered by broad alluvial deposits (Caldara & Pennetta, 1993a).

During the last glacial phase, because of the lower sea level, the Tavoliere coastland was deeply incised by rivers flowing from the Apennine chain (Caldara & Pennetta, 1996; Caldara *et al.*, 2002b).

At the end of the last glacial phase, the eastern margin of the Tavoliere took the characters of a submergence alluvial plain coast. As the sea level raised, several lagoons set on the margin of the submerging plain. Time after time, the eastern area of the Tavoliere was then characterized by a variety of transitional environments, such as dune belts, lagoons, swamps and a broad alluvial coastal plain.

In correspondence of the breaks of slope between the Gargano and the Pedegargano areas and between the Pedegargano and the Tavoliere plain, in particular at the mouths of the streams flowing down the headland, a number of alluvial fans developed during low sea level periods. These are broad sedimentary bodies made of limestone breccias whose rounded elements are well cemented in a calcareous matrix (Boenzi & Caldara, 1999).

During the middle-late Holocene a broad coastal lake set up, the Salpi Lagoon (Caldara *et al.*, 2002b). Through its history, this lagoon underwent many changes in its shape and extent. Nearly at the end of its existence, the coastal waterbody became a marshy and unhealthy land. Recently, in particular during the last two centuries, the coastal plain was subjected to reclamation. In fact, several streams have been diverted in order to facilitate the infilling of coastal depressions, such as the Versentino and Salso lakes. As a result, the alluvial sediments covered and concealed all the features that characterized the coastal plain, including the deposits of lagoon-sabkha environments (studied by Caldara & Pennetta, 1993b and Boenzi *et al.*, 2001), the dune belt that separated it from the sea (Schmiedt, 1973) and the historical lake deposits. Nowadays an enclave of the ancient lagoon exists, this is the Palude Frattarolo (Caldara *et al.*, 1994), a broad coastal swamp situated south of Manfredonia, between the Coppa Nevigata knoll and the coastline.

3. RESULTS ACQUIRED SINCE FORMER WORKS

So far in the Coppa Nevigata area four cores were studied (Caldara *et al.*, 1999; 2001; 2003b; in press c; Simone 2003). Two of those, the CN2 and CN5, were drilled in vicinity of the archaeological site, next to the lagoon shore. The other two bore holes, CN4 and CN3, were respectively made at 0.4 km and 0.8 km far from the settlement, towards the middle of the basin. The drillings at the foot of the settlement went across to sediments accumulated between before 3600 yr BP ("Avellino eruption" tephra) and recent times. A stop in

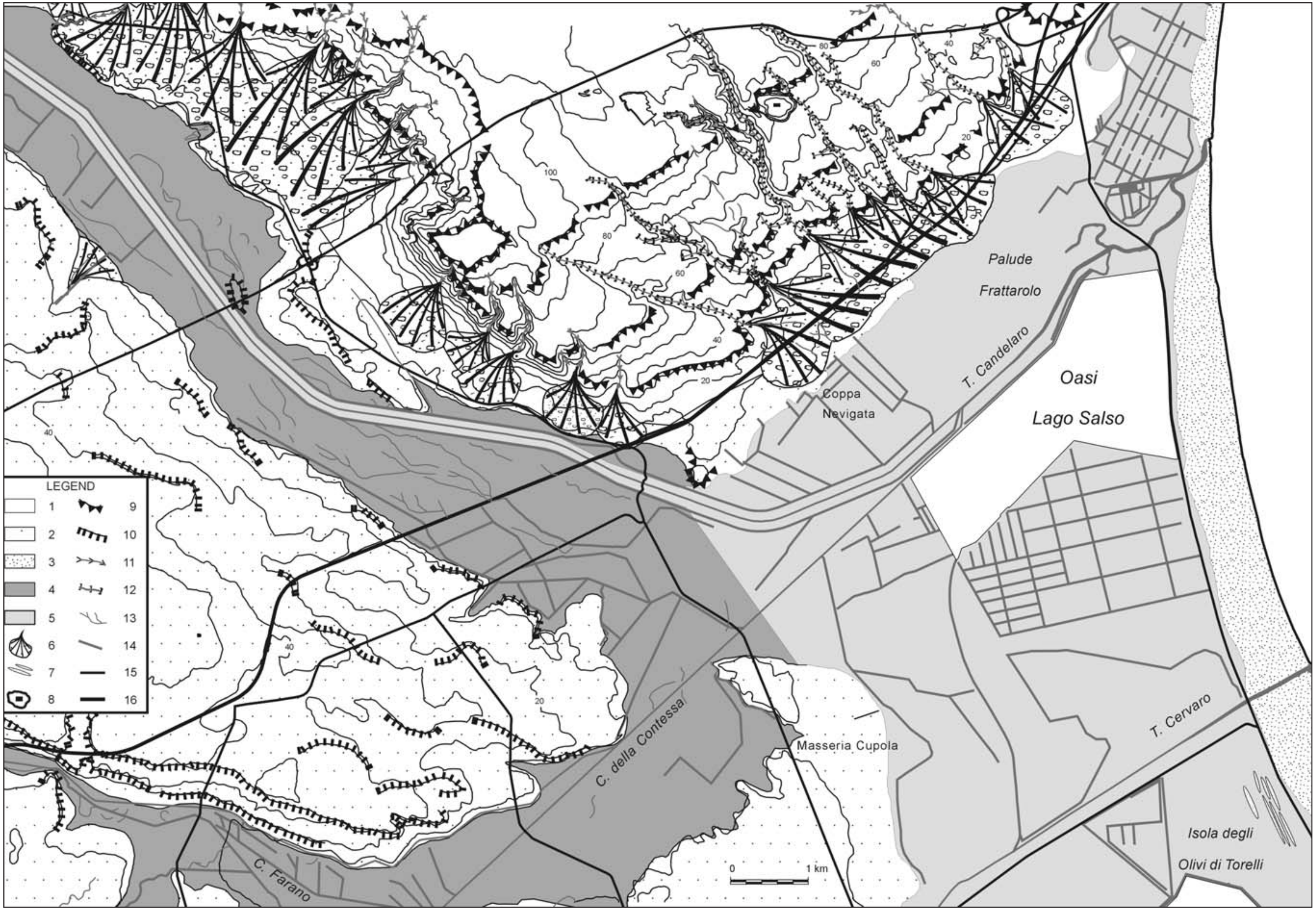

Fig 2 - Schematic geomorphological map. Key to symbols: 1 = limestone deposits (Mesozoic), Plio-Pleistocene calcarenite and Quaternary slope deposits; 2 = Tavoliere di Puglia terraced deposits (marine and fluvial); 3 = present day sand; 4 = Holocene alluvial deposits; 5 = historical reclamation sediments; 6 = alluvial fan; 7 = buried dune belts; 8 = doline; 9 = escarpment due to marine abrasion; 10 = escarpment due to fluvial erosion; 11 = "V" shaped fluvial valley; 12 = flat bottomed fluvial valley; 13 = fossil drainage, palaeo-riverbed; 14 = drainage ditch (realized to reclaim an area by drainage); 15 = road; 16 = railroad.

Carta geomorfologica schematica. Legenda: 1 = depositi carbonatici mesozoici, calcareniti plio-pleistoceniche e depositi di versante quaternari; 2 = depositi terrazzati marini e fluviali del Tavoliere di Puglia; 3 =sabbie attuali; 4 = alluvioni oloceniche; 5 =colmate storiche; 6 = conoide alluvionale; 7 = cordoni dunari sepolti; 8 =dolina; 9 = scarpata di abrasione marina; 10 = scarpata di erosione fluviale; 11 = incisione a V; 12 = incisione con fondo piatto; 13 = drenaggio fossile, paleoalveo; 14 = canale di bonifica; 15 = strada; 16 = ferrovia.

deposition, highlighted by an erosive surface, occurred between the conventional ^{14}C ages 2870±40 BP and 370±50 BP. In the middle of the basin (CN3 succession), at the bottom of the core, sediments have an age of 5580±40 yr BP. A hiatus is recorded between the conventional ages 3110±50 BP and 140±40 yr BP (Caldara & Simone, in press).

Materials found within the successions close to the settlement suggest the existence of a stable community in the nearby, particularly during the Bronze Age (Caldara *et al*., 1999; 2001; 2003b). The CN2 and CN5 series show upcore alternating terrestrial and brackish horizons. One could interpret this alternation as the expression of four negative sea level fluctuations, marked by the deposition of terrestrial/marshy sediments (Caldara & Simone, in press). On the other hand, no evidence of sea level fluctuations were found in the middle of the basin (Simone, 2003; Caldara *et al.*, in press c). According to Caldara & Simone (in press), three of the four fluctuations recognized in vicinity of Coppa Nevigata were most likely due to colonization of environments situated at the margin of the wet area, that is to say that the terrestrial/marshy environments should be considered as the expression of an aggrading coastline (whatever the cause) rather than a sea level fall.

The analysis of the CN2 and CN5 cores made possible the reconstruction of palaeoenvironmental changes occurred in the nearby of the Coppa Nevigata settlement at least from 3600 years BP.

On the basis of the fossiliferous assemblages, a descriptive name was given to each reconstructed environment (Fig. 3). These, listed starting from the most ancient, are:

3.1. Hydrobiidae spp. and Cerastoderma Lagoon

Mainly represented by clayey sediments, dominated by lagoon species, a few marine taxa occur in the lower section (Caldara *et al*., 1999, 2001).

During this first lagoon phase, two episodes conditioned the accumulation processes. The first event was the accumulation of a tephra layer containing materials from at least two different eruptions (Caldara *et al.*, 2001; 2003a). One of these has been identified as the "Avellino Eruption" of the Vesuvius, dated at about 3500 ÷ 3600 BP (Terrasi *et al*., 1999; Albore Livadie *et al*., 1998; Rolandi *et al*., 1993; Andronico *et al.*, 1995). The rest of the tephra granules could be referred to one of the eruptions occurred during the last phase (4100 ÷ 3700 yr BP) of the Phlegrean Fields activity (Caldara *et al.*, 2001; 2003a).

The second episode characterized the upper part of the Hydrobiidae spp. and *Cerastoderma* Lagoon. At this level accumulated a horizon characterized by a high organic matter content, whose principal constituents are related to human activities, such as charred seeds and fruits, cereal remains, domestic animal bones, remains of insects living in granaries or breeding in decomposing meat and pottery fragments. Given the excellent preservation state, we can say that these materials underwent a short transportation before the definitive deposition (Caldara *et al*., 1999; 2001; 2003a).

The accumulation of lagoon sediments continued until shortly after the radiocarbon date 3090±40 BP (CN5 core).

3.2. Terrestrial Phase I

The successions continue upcore with sediments accumulated under sub-aerial conditions. The first centimetres are rich in organic matter and have a similar aspect in comparison to the ones above defined. The rest of the sub-aerial horizon is a soil made of silty-clayey sediment. The findings of pottery fragments, stones and *concotto* suggest that the settlement expanded towards the plain. According to the chronological data available, these structures were built after the radiometric date 3000±80 years BP and before 2870±40 BP (Caldara *et al.*, 1999; 2001; 2003a).

3.3. Cerastoderma Lagoon

The terrestrial deposits are overlaid by grey clayey silts. The fauna, characterized by a low diversity, is dominated by *Cerastoderma glaucum* (Caldara *et al*., 2001; 2003a).

3.4. Salt Marsh I

Gradually, the lagoon environment evolved to a brackish marshy area. The lower part of this interval is characterized by clayey silts with thin arenaceous beds, whereas in the upper part there are calcareous lumps and thin black levels made of organic matter. This environment was described as a salt marsh (Caldara *et al.*, 2001; 2003a).

3.5. Hydrobiidae spp. and Abra segmentum Lagoon

The sediments that constitute this third lagoon episode are clayey silts with pebbles in its lower part, silts with thin black organic matter levels and calcareous lumps in the upper part. The macrofauna is represented mostly by lagoon taxa. Progressively the environment underwent a relative lowering of the water level.

3.6. Terrestrial Phase II

This is a new terrestrial phase whose sediments are clayey silts dark-grey in color, with several thin organic matter levels and small calcareous lumps. The fauna is characterized by a mixed assemblage made of broken terrestrial mollusc shells and young individuals of lagoon species.

3.7. Salt Marsh II

This environment is represented by dark gray clayey silts with alternating calcareous levels. The mollusc fauna is poor and dominated by Hydrobiidae, few young individuals of *Cerastoderma glaucum* and *Abra segmentum* also occur.

3.8. Arid or semiarid Terrestrial Phase

It is not clear yet when the salt marsh sediments stop to accumulate. In fact, these are cut by an erosive surface. A sub-aerial period, under arid or sub arid conditions, is testified by the formation of calcareous crust levels and lumps.

3.9. Bithynia leachi and Ovatella myosotis wetland

Shortly before the radiocarbon date 370±50 BP, the area at the foot of the Coppa Nevigata hillock was submerged by fresh water. The sediments accumulated in this interval are sandy silts rich of *Ovatella myosotis* and *Bithynia leachi.*

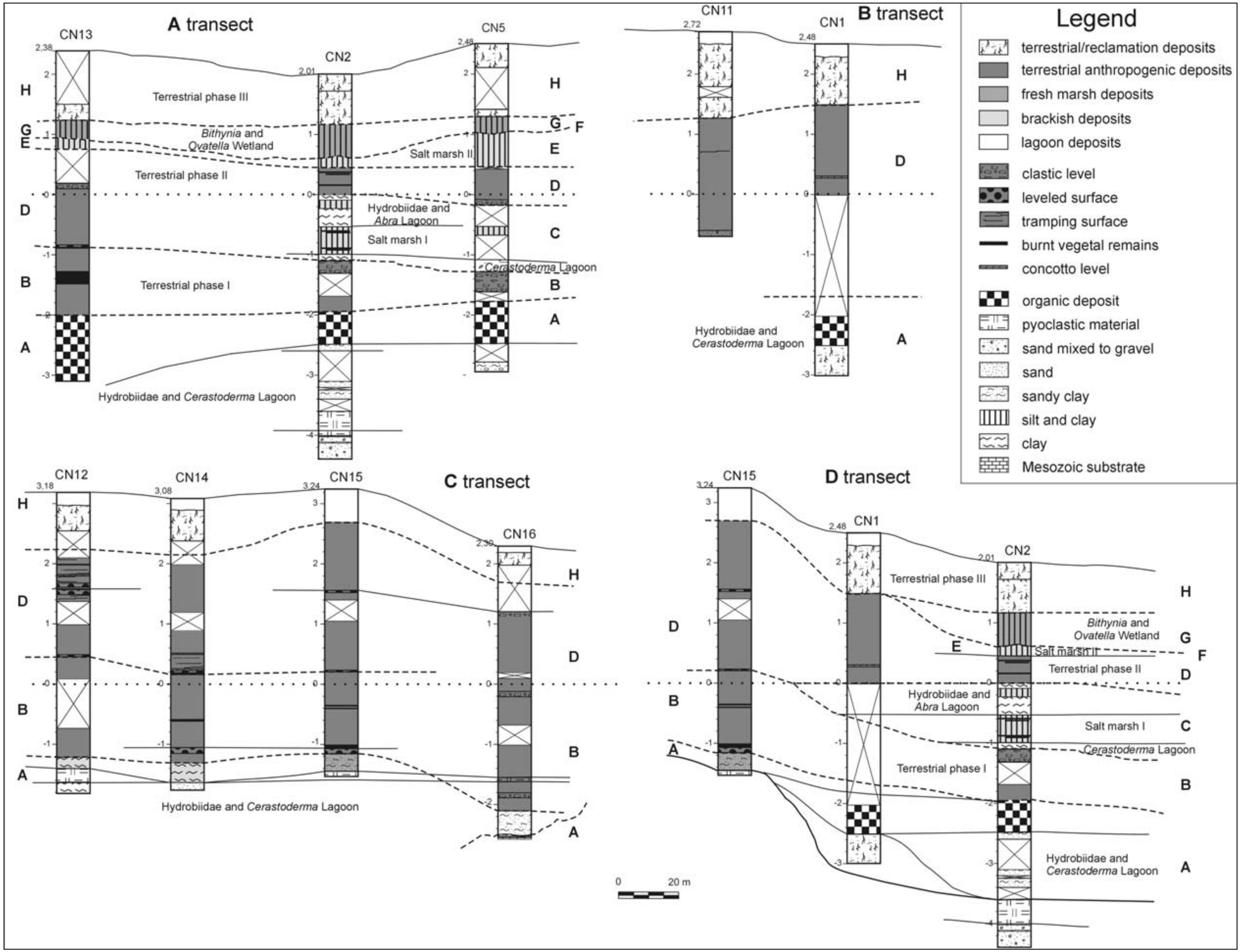

Fig. 3 - Stratigraphic correlations among the studied cores. The **A**, **B**, and **C** transects are parallel, while the D alignment is perpendicular to the first ones. Beside the transects, the **A - H** letters refer to the recognized phases, while the terminology used is the same as in literature.

*Correlazioni stratigrafiche. Sono disegnati i transetti **A**,**B**,**C** paralleli fra loro e **D** perpendicolare. Sono riportati a fianco dei transetti le lettere **A-H** riferite alle fasi d anche la terminologia degli ambienti come definita in letteratura.*

3.10. Terrestrial Phase III

The very upper part of the CN2 and CN5 cores is made of silty-clayey soil, densely laminated and scarcely pedogenized. The faunistic content, mostly terrestrial shell fragments, is scarce.

4. DESCRIPTION OF THE STUDIED SUCCESSIONS

For convenience the successions were grouped in three transects and described in function of their distance from the settlement. In particular, in the **A** group there are three successions drilled at the foot of the Coppa Nevigata knoll; the **C** group consists of four series sampled close to the settlement; in the **B** transect there are only two cores drilled in the middle between the **A** and **C** groups (Fig. 1).

4.1. A transect - CN13, CN2 and CN5 cores

These three cores show a great lithological variability (Fig. 3), due to the thick alternation of deposits accumulated in natural conditions or under the more or less direct anthropic influence. The environments formerly reconstructed for the CN2 and CN5 cores show a good mutual correspondence (Caldara *et al.*, 1999; 2001). On the other hand, only the lower and higher sections of the CN13 core could be correlated in a satisfactory way with the homologue environments reconstructed for the CN2 and CN5 cores.

At the bottom, the CN2 and CN5 cores show lagoon deposits, mostly clayey (Hydrobiidae and *Cerastoderma* Lagoon; Caldara *et al*., 1999; 2001; 2003a; in press a). Between 4.05 m and 3.60 m below m.s.l. (CN2 core) the accumulation of tephra deposits occurred (Caldara *et al*., 2001; 2003a).

In both the CN2 and CN5 cores the upper section of the Hydrobiidae and *Cerastoderma* Lagoon and the lower part of the overlaying terrestrial sediments are characterized by the accumulation of an organic sediment, dark in colour, mainly made of heterogeneous material originated after the activities carried out at the settlement during the Bronze age (Caldara *et al*., 2001; 2003a; in press a). In the CN13 core the accumulation of this kind of sediments started under brackish conditions and continued in a paludal environment dominated by fresh water molluscs.

The series continue upcore with terrestrial deposits (Terrestrial phase I; Caldara *et al*., 2003a). These sediment are clayey to sandy, grey or reddish-grey, with small calcareous lumps, calcareous crust fragments, pottery fragments and broken domestic animal bones (ox, pig, sheep, dog etc.). In the CN13 core, between 1.49 m and 1.29 m below m.s.l., there is a thin black horizon made of tiny charcoals. Another charcoal level, about one centimetre thick, lies under a leveled surface[1]. *Concotto* fragments, limestone and sandstone clasts have been found at several levels within the CN2 and CN5 successions. These findings were attributed to the remnants of a wall structure (Caldara *et al.*, 1999; 2001; 2003a; in press a).

In the following section, up to the present day sea level, the sedimentation around the three bore holes occurred under different conditions. In particular, the sediment in the CN2 and CN5 successions is a lagoon clayey silt (*Cerastoderma* Lagoon, CN2 core, Caldara *et al.*, 2001; Hydrobiidae Lagoon, CN5 core, Caldara *et al.*, 1999). Upcore the lagoon evolved to a more superficial environment in which accumulated clayey silt rich in organic matter characterized by young individuals of brackish taxa (Salt marsh I in Caldara *et al.*, 1999; 2001; 2003a).

The upper part of this section is again represented by lagoon clayey silt (CN2 core). The assemblages are dominated by lagoon taxa, the other accompanying species belong to the marine domain (Hydrobiidae and Abra Lagoon in Caldara *et al*., 1999; 2001; 2003a).

On the other hand, the corresponding section of the CN13 core is characterized by sediments virtually similar to the ones that lay directly below, i.e. dark silt with dispersed calcareous crust fragments, charcoals and pottery fragments.

Between 0 m and 0.40 m circa above m.s.l. the successions recorded a new terrestrial phase (Terrestrial phase II, Caldara *et al.*, 2003a), with the accumulation of clayey to sandy silt. Several organic levels and dispersed small calcareous lumps also occur. The assemblages are made of terrestrial mollusc fragments and young individuals of brackish taxa. Some domestic and wild animal bones also occur (Caldara *et al*., 1999; 2001). Burnt bone fragments and marine gastropods have been found within thin dark levels in the CN2 core.

The successions continue upcore with dark grey silt accumulated in brackish-marshy environments (Salt marsh II, Caldara *et al.*, 1999; 2001; 2003a). The fossil association is made of scarce brackish molluscs, foraminifers and ostracods. These sediments are cut by an erosive surface, marked in the CN2 and CN5 cores by a thick accumulation of a secondary calcareous crust, originated by groundwater evaporation.

On the erosive surface lays a sandy silt deposit with fresh water fauna. The reconstructed environment is a marshland characterized by a variable fresh water covering (*Bithynia* and *Ovatella* Wetland, CN2 core; *Bithynia* Wetland and *Ovatella* Wetland, CN5 core. Caldara *et al.*, 1999; 2001; 2003a).

The very upper part of these three sequences is made of soil disturbed by the intense ploughing activities (Terrestrial phase III, Caldara *et al*., 2003a).

4.2. B transect - CN11 and CN1 cores

In this group there are only two cores (CN11 and CN1, Fig. 3). Despite the care taken during coring activities, there have been two metres of sample loss in the CN1 core. Thus we were able to correlate these successions only in a partial way. Further data should be collected with additional cores.

The lower part of the CN1 succession, is a grey-greenish clayey sediment, somewhere sandy. There are scattered charcoals, calcareous crust fragments and domestic animal bones (sheep). Between 2.50 and 2.00

[1] With "leveled surface" we mean a surface made regular by spreading of fine sediment, whatever it is (generally calcareous or clayey). The use to spread material in order to regularize the ground is well known to the archaeologists that worked on the Coppa Nevigata site.

m below m.s.l. the sediment is dark, compressible and rich in vegetal detritus. In the whole this deposit is quite similar to the high organic deposit found in the CN2 and CN5 cores (Caldara *et al*., 2003a).

From the base of the CN11 core and above the two metres gap in the CN1, the two drillings went across to fine sediments, mostly clayey, greyish to dark, hardly stratified, deposited under the direct anthropic influence (scattered bone fragments, charcoals, Bronze age pottery fragments).

In three occasions the core sediments differ from the general pattern above described. In particular, at the bottom of the CN11 core, there is a rudite horizon made of heterogeneous materials, such as lithic fragments (limestone crust and siliceous pebbles), bones, pottery, terrestrial molluscs and charcoals. In the CN1 core, at circa 0.30 m above m.s.l., there is a reddish concotto horizon six centimetres thick. Finally, in the CN11 core, at 0.70 m above m.s.l., a horizon made of calcareous crust fragments suggests the presence of a probable leveled surface.

The two successions continue with a brown clayey soil with small lithic fragments. The upper part of this soil is deeply disturbed by ploughing.

4.3. C transect - CN12, CN14, CN15 and CN16 cores

In this group there are the successions drilled close to the settlement. The lower part of the sequence accumulated under mostly natural environments (lagoon, salt marsh and fresh marsh), the upper part is made of sediments deposited under the more or less direct anthropic influence.

The CN16 core is the only one that reached the limestone substrate in this area. The transgression surface, cut on Cretaceous limestone, is marked by holes made by marine molluscs and sponges and covered by a thin calcareous sand with marine shell fragments (*Ostrea*, *Mytilus* and *Pinna*). Rapidly, the assemblage becomes typically lagoonal (*Cerastoderma glaucum*, *Abra segmentum*, *Cyclope neritea and Ammonia beccarii* and *Haynesina germanica*). The same fauna characterizes the overlaying clayey deposit.

We considered natural the sediments accumulated at the base of the CN12 core (up to 1.22 m below m.s.l.). In particular, between the base and 1.66 below m.s.l., the sediments are silty with tiny vertical roots and characterized by lagoon taxa (*Abra segmentum*, Hydrobiidae, *Haynesina germanica* and *Ammonia beccari*). In the middle part of this section there are three volcanoclastic horizons (Fig. 4D). The first one, the thicker, has a fairly regular base, whilst the contact between the other two and the sediment below is less evident. Between the horizons with tephra some volcanic granules occur scattered within the sediment. The faunistic assemblages indicate a lagoon environment. Between 1.40 and 1.22 m below the m.s.l. the sediment is silty-sandy. The collected fauna (mostly *Ovatella myosotis* and *Truncatella subcylindrica*) suggests a salt marsh environment with some fresh water input (occurrence of *Bithynia leachi*).

At the bottom of CN14 succession (Fig. 4A) there is a yellowish sand level with *Cerastoderma glaucum*, *Abra segmentum* and Hydrobiidae; several *Bithynia leachi* also occur. A sharp contact separates the sand from a greyish clay layer accumulated in an almost natural environment. The clayey unit could be subdivided in three horizons. The lower and the upper ones are characterized by a thick lamination due to the presence of organic detritus (Fig. 4E). The central part is made of massive clay with subvertical tiny roots. Faunal assemblage is dominated by brackish organisms: *Ovatella myosotis* and *Truncatella subcylindrica*, some miliolids (*Quinqueloculina* spp.). We interpreted this environment as a salt marsh.

The natural deposit at the lower end of the CN15 succession is a silty sand made mostly by tephra granules mixed to lagoon molluscs (Hydrobiidae and *Abra segmentum*), foraminifers and ostracods. The upper part of the natural deposit is represented by a fine grey-greenish sediment, slightly sandy, with fragments of reworked molluscs, perhaps accumulated in a marshy environment.

The rest of the sequence accumulated under the more or less direct anthropic influence. In all the cores the contact between natural and anthropogenic sediments is sharp and occurs at similar elevations in the CN12, CN14 and CN15 series, while it is deeper in the CN16 core. The anthropogenic sediments are porous, dark grey, with scattered Bronze age pottery fragments, concotto, lithic tools, domestic animal bones (sometimes burnt), marine shells (*Phyllonotus trunculus*) and charcoals. The bedding planes are hardly visible, except when the drillings went across to black hearth material, *concotto* levels, tramping and/or leveled surfaces and structures in use for a considerable time span (Fig. 4A).

A number of leveled surfaces have been found in all the drillings in this group. These are well evident in the CN12, CN14 and CN15 cores, because realized with materials very different (in colour and nature) from the rest of core sediments. In some cases the surfaces were leveled by spreading a fine yellowish calcareous sediment, originated from the weathering of the Mesozoic limestone that outcrop in the nearby area (Fig. 4C). In other cases the material spread to create a plain surface is a clayey sediment with high carbonates content. Several tramping surfaces lay around the same elevation. The deeper surface lays at 1.06 m below m.s.l. in the CN14 and CN15 cores (Fig. 4F). There is, in the same two cores, another yellowish surface at 0.19 m above m.s.l., while in the CN12 and CN15 series, drilled at a greater distance, a leveled surface lays around 1.5 m above present day sea level.

The upper part of the CN12 core (between 1.44 and 2.08 m above m.s.l.) and the middle of the CN14 core (between 0.17 and 0.49 m above m.s.l.) are characterized by two horizons with many superimposed thin levels, made of alternating fine yellowish and greyish sediments, charcoal levels, brown soil, *concotto* etc. (Fig. 4B). We think that at those horizons the cores went across to structures in use for a long time span (e.g., a hut).

On the other hand, in the CN16 core the leveled surfaces seem to have been realized with a different technique. In fact, these are just a few centimetres thick and realized with limestone, calcarenite, siliceous pebbles and calcareous crust fragments.

The upper part of the CN12, CN14 and CN16 continue with a brown clayey soil with small lithic fragments deeply disturbed by ploughing.

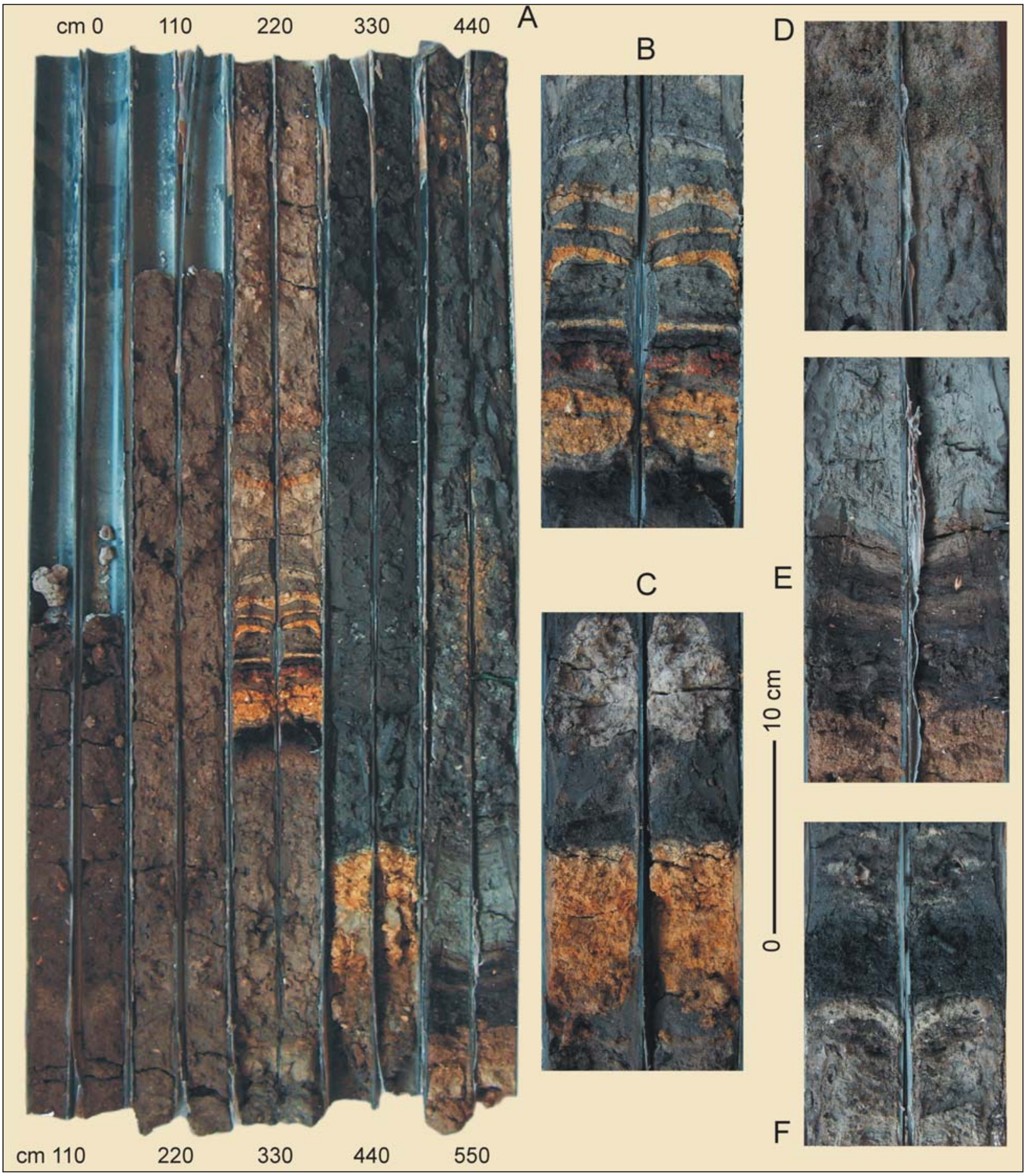

Fig. 4 - CN 14 core (A) and close ups of some cores (B-F): B = CN14 core, **D** phase, alternation of yellow and grey sediments used to level the ground, red *concotto* levels and black burnt hearth grounds; C = CN12 core, **D** phase, two beds, yellow and grey, of material spread to level the ground; D = CN12 core, **A** phase, silt with tiny vertical roots, lagoon taxa and volcanoclastic horizon; E = CN14 core, **A** phase; from the bottom: yellowish sand with lagoon fauna, thick lamination due to the presence of organic detritus and greyish clay (salt marsh); F = CN15 core, **B** phase, grey sediment spread to level the ground and a black horizon of burnt vegetal remains. Except for the CN1, CN2 and CN5 cores, got by an hydraulic corer, all the other cores (among which the ones above) were obtained by a percussion drilling machine.

*Carotaggio CN 14 (A) e particolari di alcune carote (B-F): B = CN14 perforazione, fase **D**, alternanza di piani battuti gialli e grigi, con livelli rossi di* concotto *e neri di suoli bruciati; C = perforazione CN12, fase **D**, due battuti giallo e grigio; D = perforazione CN12, fase **A**, limi con sottili radici verticali sormontati da un orizzonte vulcanoclastico caratterizzati da faune lagunari; E = perforazione CN14, fase **A**, sabbie giallastre con fauna lagunare sormontate da argille sottilmente laminate ricche di sostanza organica che passano ad argille grigie massicce con tracce di radici. L'ambiente delle argille è di salt marsh; F = perforazione CN15, fase **B**, piano battuto di colore grigio sormontato da un orizzonte di resti vegetali combusti. Le carote CN1, CN2 e CN5 sono state ottenute con una macchina idraulica, per tutte le altre (tra cui quelle in figura) è stato utilizzato il metodo di carotaggio a percussione.*

5. EVENTS RECONSTRUCTION

Due to the elements collected after this study we can give a tentative reconstruction of the events at the foot of the Coppa Nevigata knoll. The events succession is described starting from the most ancient one (Fig. 3).

5.1. A phase - natural phase I

The natural phase **A** is characterized by environments with different peculiarities, but under absent or minimal human influence. This phase has been recognized in almost all the successions, except for CN11 (that did not reach those levels) and CN1 (whose bottom is characterized by probably colluvial sediments).

The CN16 core is the only one that reached the Cretaceous limestone substrate and presenting evidence of marine sedimentation. Above this episode and within the other drillings, the sediments are dominated by lagoon species. The lagoon environment in the external (distal) successions (**A** transect) is characterized by salinities ranging between 25 and 18‰ (after molluscan analysis). The correspondent section, in the internal (proximal) cores (**C** transect), drilled at higher elevations, seem to be conditioned by a lower salinity. All those lagoonal deposits can be related to the "Hydrobiidae and Cerastoderma Lagoon" found in the CN2 and CN5 cores.

The cores at the western end of the **C** transect (CN12 and CN14) show, above the lagoon sediments, salt marsh deposits. On the other hand, in the CN15 core the lagoon sediments are overlain by deposits accumulated in a dry environment at the edge of a fresh marsh.

Among the **A** transect drillings, pyroclastic deposits were found only in the CN2 core (Caldara *et al*., 2001; 2003a), whilst in the **C** transect tephra are present in the CN12 (Fig. 4D) and CN15 cores. Tephra deposits have been found in marginal lagoon environments, within the proximal cores. The thickness of these deposits, as well as the depth, increases with the distance from the centre of the settlement. This should confirm what hypothesised in Caldara *et al*. (2003a), that is there was first a phase of tephra accumulation due to direct fall on a large surface characterized by different environments, followed by erosion and secondary deposition in low areas.

The organic deposit (Caldara *et al.*, 2001; 2003a, in press a) has been found in all bore holes in the **A** transect and in the deeper one in the **B** transect, while it is not present next to the settlement (**C** transect). The maximum thickness of this deposit occurs in CN13 core (**A** transect). At this point it looks more probable that the deposition of the organic horizon is due to washing processes acting along the slopes of the Coppa Nevigata knoll, rather than intentional accumulation of material dumped by man next to the lagoon edge (Caldara *et al*., 2003a; in press a).

In conclusion, in the natural phase **A** there are lagoon (Hydrobiidae and *Cerastoderma* Lagoon), salt marsh (*Ovatella myosotis* facies), paludal and colluvial deposits, with abundant input of sediments from the settlement.

5.2. B phase – terrestrial phase I

This phase corresponds to the terrestrial phase I (Caldara *et al.*, 2003a) in the **A** transect cores and probably in the **B** transect and seems to start during the Early Sub-Apennine (Caldara *et al*., 2003a; in press a).

The erosive surface that separates the **A** phase from the **B** phase sediments appears as sloping towards the middle of the lagoon except for the CN16 core, where a depression is outlined. Actually, the CN16 core represents an anomaly; in fact, in this succession the pyroclastic horizon occurs in the **B** phase and not in the natural interval. This drives us to hypothesize that the area around the CN16 core, no longer lagoonal, were utilized by the Coppa Nevigata community from the Cetina phase (Recchia, 2002), or at least from the Early Bronze Age (before the "Avellino" event).

The **B** phase is characterized by the occurrence of the first leveled surfaces (CN14 and CN15 cores, Fig. 4F) and by a thick accumulation of burnt material (CN13 core).

The end of the **B** phase is well identifiable within the distal cores (CN2 and CN5) because of the return of brackish conditions. In the other cores the **B** phase seems to be in continuity with the **D** phase. Tentatively we put the limit between the **B** and **D** phases at the base of the yellowish tramping surfaces slightly above the sea level within the **C** transect cores, and at the base of a tramping surface laying at 0.82 m below m.s.l. in the CN13 core.

5.3. C phase - natural phase II

At the moment the C phase has been recognized only for the distal cores (CN2 and CN5), while we hypothesize its continuity in the area around the cores of the **B** transect (Fig. 3), this should be assessed by means of new drillings. In other words, the setting of the natural phase II seems as occurred only in the northern part of the studied area, facing the present day coastline (Fig. 1).

The natural phase II is characterized by the succession of three brackish environments, i.e. *Cerastoderma* Lagoon, Salt marsh I and Hydrobiidae and *Abra segmentum* Lagoon (Caldara *et al*., 1999; 2001). These environments have been correlated to the Hydrobiidae and *Cerastoderma* Lagoon, recognised in the middle of the basin (CN4 and CN3 cores; Caldara & Simone, in press). This phase occurred between the Final Bronze and a not well defined Iron Age (Caldara *et al*., 2003a).

5.4. D phase – terrestrial phase II

In the distal area (**A** transect cores), the **D** phase corresponds to the terrestrial phase II (Caldara *et al*., 2003). This one represents a new phase of occupation of the areas freed by lagoon waters. The lagoon retreat seems to have been occurred because of natural causes (Caldara & Simone, in press).

We do not know exactly when this phase developed, perhaps between the Iron Age and Roman period (Caldara *et al.*, 2003a; in press a).

The erosive surface that separates sediments pertinent to the **C** and **D** phases lays around 0 m in the distal area (**A** transect), whilst within the **B** and **C** transect cores, given the similar characteristics that sediments show, the limit between **B** and **D** phases is somewhat undefined.

The **D** phase is characterized by a number of tramping/leveled surfaces. These can be single (CN15) or superimposed, sometimes there is an alternation of tramping/leveled surfaces, *concotto* levels and burnt hearth grounds (CN12 and CN14, Fig. 4B,C).

As regards to the distal area (CN2 and CN5 cores), given the findings of burnt soils and domestic bone fragments, Caldara *et al*. (in press a) hypothesized a pastoral-agricoltural land use. Nevertheless, the evidence collected with this study suggests that, at the foot of the knoll, several simple inhabitation structures were in existence during the various occupation phases.

5.5. E phase - natural phase III

The **E** phase has been identified only in the distal drillings (**A** transect) and corresponds to the salt marsh II (Caldara *et al.*, 2003a). Therefore, the recovery of natural environment seems has been occurred in the areas at the external margin of the settlement.

The **E** phase sediments are cut in their upper part by an erosive surface. Their chronological position is not well defined yet. In addition there were not found any anthropogenic indicators, therefore we think that, during the deposition of the **E** phase sediments, the Coppa Nevigata knoll was not inhabited. The more recent findings are VI century BC pottery fragments (Pallottino, 1951); that could mean that the **E** phase sediments accumulated successively.

5.6. F phase - arid terrestrial phase

The **F** phase did not leave sediments; it is recognizable because of two elements, i. e. the erosive surface that cut the paludal deposits in all the distal cores (**A** transect) at different elevations and the presence of calcareous crusts and lumps (evaporite) in the upper part of **E** phase sediments. These features suggest a subaerial phase characterized by a marked pedogenesis. The thick calcareous crust indicates arid conditions lasting for a long span of time. That is why we called this phase "arid terrestrial".

At the moment we are not able to say how long the terrestrial phase lasted and when the erosion occurred. The only chronological indication comes from the stratigraphic position of this event.

5.7. G phase - natural phase IV

The **G** phase corresponds, in the distal area (**A** transect), to the *Bithynia* and *Ovatella* Wetland (Caldara *et al.*, 2003a).

In the lower part of the **G** phase sediments the environment seems to be fairly brackish, whilst in the upper part the waterbody is exclusively conditioned by fresh water input.

Radiocarbon data, 370±50 yr BP (CN2 Caldara *et al.*, 2001) and 140±40 yr BP (Simone, 2003), suggest that this wet area was set around the end of the Middle Ages.

Documentary data show that this wet area (part of Salso and Versentino lakes) reached its maximum development around the end of the XVIII century (Caldara *et al*., 2002b), after the ruinous floods of the Cervaro and Carapelle streams in 1795 (Giustiniani, 1797 - 1805).

5.8. H phase – historical reclamation

These sediments correspond to the terrestrial phase III in Caldara *et al*. (2003a). The **H** phase is well recognizable within the **A** and **B** transects, while is less apparent in the **C** transect because of a loss of sample occurred during coring operations. Nevertheless, these sediments cover both **E** phase (natural wet area) and **D** phase sediments (anthropogenic).

The accumulation of the **H** phase deposits occurred after reclamation projects carried out through the diversion of the Candelaro stream. The very upper part of this interval is deeply disturbed by ploughing activities.

6. CONCLUSIONS

By this research, in the Coppa Nevigata area we reconstructed eight different phases grossly attributable to two different evolution patterns (Fig. 3). The first one includes sediments intentionally accumulated or reworked by man. The latter includes deposits which sedimentation was basically driven by natural processes, even though materials accumulated are often directly due to man activities at the settlement.

We ascribed to the "anthropogenic" pattern the **B**, **D** and **H** phases. The "natural" pattern includes the phases **A**, **C**, **E**, **F** and **G**.

We found the anthropogenic sediments (**B** and **D** phases) underground, up to circa 90 m from the nearest trenches dug by archaeologists (Fig. 1). These deposits were not found within the CN4 and CN3 cores, drilled respectively 400 and 800 m far from the settlement (Caldara & Simone, in press). On the contrary, the CN3 and CN4 cores show that the Hydrobiidae and *Cerastoderma* Lagoon persisted without interruptions from the Neolithic to the Iron age (Caldara *et al*., 2003b). Therefore, we correlate the Hydrobiidae and *Cerastoderma* Lagoon found in the CN3 and CN4 cores to the **A**, **B**, **C**, **D** and **E** phases identified close to the settlement.

At the moment it is not possible to distinguish the limit between the anthropogenic **B** and **D** phases within the successions of the **C** group (next to the settlement), while these are well distinguishable in the distal **A** group.

Even though directly related to anthropogenic activities carried out at the settlement, we defined as "natural" the high organic content material included in the **A** phase. We consider these sediments as washed out along the side of the knoll and deposited in a hollow at its foot, instead of intentionally disposed by man in a dumping area. The developing of the **B** phase seems to have been started from the most internal settlement areas (CN14 and CN15 cores). This would be in accordance with a urbanization phase occurred within the perimeter described by joining the hypothetical buried parts of defensive wall found by geophysical analysis (Fig. 1). On the other hand, the presence of hearths in distal areas (CN13) could be attributed to activities carried out outside the defensive wall system.

As regarding the **D** phase (anthropogenic), by the study of the CN2 and CN5 cores (in the distal area) Caldara *et al*. (in press b) assumed an agricultural-pastoral land use for those levels. After this study, given the presence of a number of single or multiple (superimposed) tramping/leveled surfaces in association with *concotto* and hearths levels (CN12, CN14 and CN15), we can hypothesize, at least for the areas surrounding the settlement, the persistence of simple inhabitation/occupation units.

The **B** and **D** anthropic phases recorded within the CN16 sediments are worthy of further analyses. In particular, the first consideration is that around the CN16 drilling site the colonization occurred earlier than other investigated places within the Coppa Nevigata area. In that case the first post Neolithic occupation phases would be occurred at least starting from the Early Bronze age (before the "Avellino" event) or perhaps from the Cetina phase (Recchia, 2002). In addition, the CN16 core suggests a use of the area outside the Apennine defensive system (part of the wall has been found beneath the surface by geophysical surveys; Fig. 1).

The **H** phase considerably differs from the two above mentioned **B** and **D** anthropic phases. The **H** phase deposits accumulated after direct anthropic actions, even though sedimentation processes occurred under almost natural conditions. In fact, during the XIX century, the Candelaro and Cervaro streams used to wander in the coastal plain without flowing into the sea through a defined mouth. As a result, great part of the Tavoliere coastal area was marshy and unhealthy (Caldara *et al.*, 2002b). For this reason in that period challenging reclamation projects have been conceived (Afan de Rivera, 1838; 1845). To protect their fields from frequent floodings the landowners started to build embankments. Subsequently, the Candelaro and Cervaro streams were partially (sometimes totally) diverted towards the hollows (surrounded by artificial dikes) in order to fill them by siltation. In particular, the Candelaro stream was embanked and its mouth was progressively shifted downstream towards the middle of the former Salso lake. As examples we quote here reclamation works made between the 1869 and the 1909 (Pareto, 1865; historical maps by the Italian Military Geographical Institute), in 1939 (Rotella 1984) and after the World War II.

By this study we described the evolutionary mechanisms, both anthopic and natural, that acted in the Coppa Nevigata area since the Neolithic. Nevertheless, several problems have to be fixed in the future. In particular we found that correlations among the group **B** cores are not reliable, thus should be useful to drill more cores around the CN1 site. The chronology of the **B** and **D** anthropic phases, well defined for the distal drillings, is not verified for those close to the settlement (**C** group) and raises perplexities among the archaeologists.

In addition, the area around the CN16 core should be investigated, in order to verify the existence of an early colonization phase occurred outside the walls and define the limits of the bulge in the limestone substrate (Fig. 3).

An other arousing question is from where the Coppa Nevigata inhabitants supplied material used for ground leveling and to realize the tramping surfaces.

In conclusion, it is apparent how man was able, through time, to modify the surrounding environment, in particular during the Middle Bronze (**B** phase), the Iron age (**D** phase) and during the last two centuries. Even when the accumulation of sediments occurred under almost natural conditions, anthropogenic activities conditioned the environment evolution, such as during the deposition of the high organic content sediments in the **A** phase and during the **C** phase.

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