GEO-ARCHAEOLOGICAL IMPLICATIONS OF RIVER AND COASTAL DYNAMICS AT THE POTENZA RIVER MOUTH (THE MARCHES, ITALY)

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ABSTRACT

In this contribution, the coastal and fluvial dynamics in the Potenza river plain (the Marches, Italy) are discussed, with the spatial and temporal extension of their associated features, to the degree of detail possible with the evidence at hand; and with their implications on archaeological site formation in its broadest sense, though focused on the Roman period (2nd century BCE – 7th century CE) and the roman city Potentia. The results, both concerning fluvial and coastal dynamics, could be fitted into the general story for the Marche region, as found in literature.

The coast, starting off with an alternation of cliffs and bays during the Versilian transgression, was transformed into a beach barrier-lagoon system with a marine terrace at the base of the cliffs after the mid-Holocene, once the sea-level rise slowed down. Potentia was built on such a beach barrier. Behind the barriers, sediments were deposited, shaping the coastal plain in two distinct phases, one phase of land formation by deltaic fluvial infill, and a post-medieval phase with clay-deck formation by floods.

The fluvial dynamics include river diversions, from a central position in the coastal plain started before the Bronze Age, via a Roman and medieval course debouching 0.5 km more to the north, to the present artificial course in the extreme north of the coastal plain.

These alternations of the physical environment had their implications on the archaeological record, influencing amongst others: the location of the harbour of Potentia, the extension of the city towards the east, the implications for geoelectrical and geomagnetical survey, the form of the Roman road pattern, the impact on river management options and the choice of site locations for production.

KEY WORDS

Potenza river, the Marches, Italy, PVS, coastal plain, river diversion & avulsion, geoarchaeology, Holocene, Potentia.

RIASSUNTO

In questa contribuzione, le dinamiche costiere e fluviali nella pianura del fiume Potenza (Le Marche, Italia) sono trattate, inclusivo un tentativo di reconstruirne l'estenzione spaziale e temporale, ed inclusivo le loro implicazioni sulla formazione degli siti archeologici nel senso più ampio, con fuoco sul periodo romano (II secolo ante Christo – VII secolo dopo Christo) e la città romana di Potentia. I risultati, delle dinamiche fluviali e costiere ambedue, s'inseriscono nella storia delle Marche ritrovata nella letteratura.
La costa, cominciando con un'alternazione falesie-baie durante la trasgressione Versiliana, dopo la metà del Holocene si trasforma in una disposizione cordone littorale-laguna e una terrazza marina sotto le falesie, in concomitanza della diminuzione della velocità del livello del mare. Potentia era costruita su uno di questi cordoni littorali. Dietro le cordone, la deposizione di sedimenti modellava la pianura coastiera di oggi in due fasi: una con l'interrarsi della pianura per sedimentazione fluviale deltaica, ed una fase post-medievale con la formazione di una copertura limosa-argillosa per inondazioni.
Le dinamiche fluviali includono le diversioni del fiume, di una posizione centrale nella pianure costiera iniziata prima del età del bronzo, a traverso un tragetto romano e medievale 0,5 km più a nord, fino al corso artificiale di oggi, al nord estremo della pianura.
Queste alternazioni del contesto fisico hanno formato il record archeologico in diversi modi, influenzando tra l'altro: la posizione del porto di Potentia, l'estenzione verso oriente della città, le implicazioni per lo studio geo-elettrico e geomagnetico della pianta della città, la disposizione del reticolato viario, l'impatto sulle scelte in gestione fluviale, e la scelta di luoghi per l'implantazione di nuovi siti produttivi.

TERMINI CHIAVE

Fiume Potenza, Le Marche, Italia, PVS, pianura costiera, diversione di fiumi & avulsione, geoarcheologia, Olocene, Potentia.

INTRODUCTION

The Potenza river – in the Marches region in central Italy – rises in the central Apennines and discharges into the Adriatic Sea. Its 80 km long and about 10 km wide WNW-ENE-trending fluvial basin (775 km^2) is parallel to the neighbouring streams (Fig. 1).

From 2000 onwards, selected areas in this river basin have been studied in the framework of the international geoarchaeological "Potenza Valley Survey" (PVS) project[1]. The most fascinating and best studied of these areas, both in terms of geomorphological evolution and in terms of archaeological richness, is the coastal area.

Numerous studies exist on the geomorphology of the Marches river basins and abundant texts on the archaeology of the region have been published. The interface of both sciences in the central Marches region was tackled by Mauro Coltorti and Giuseppe Cilla and more recently by the team of the University of Camerino Geological Sciences department; but not for the Holocene and historical changes in the coastal plain of the Potenza river. Consequently, a detailed study was executed as part of PVS-project, encompassing literature review and aerial photograph interpretation, a full-scale augering campaign, qualitative electrical resistivity measurements (adjusted pole-pole configuration), topographic survey, radiocarbon and OSL dating, mollusc analysis, three large archaeological survey campaigns and collaboration with the local archaeologists of the Soprintendenza per i Beni Archeologici delle Marche (Goethals & alii, 2006).

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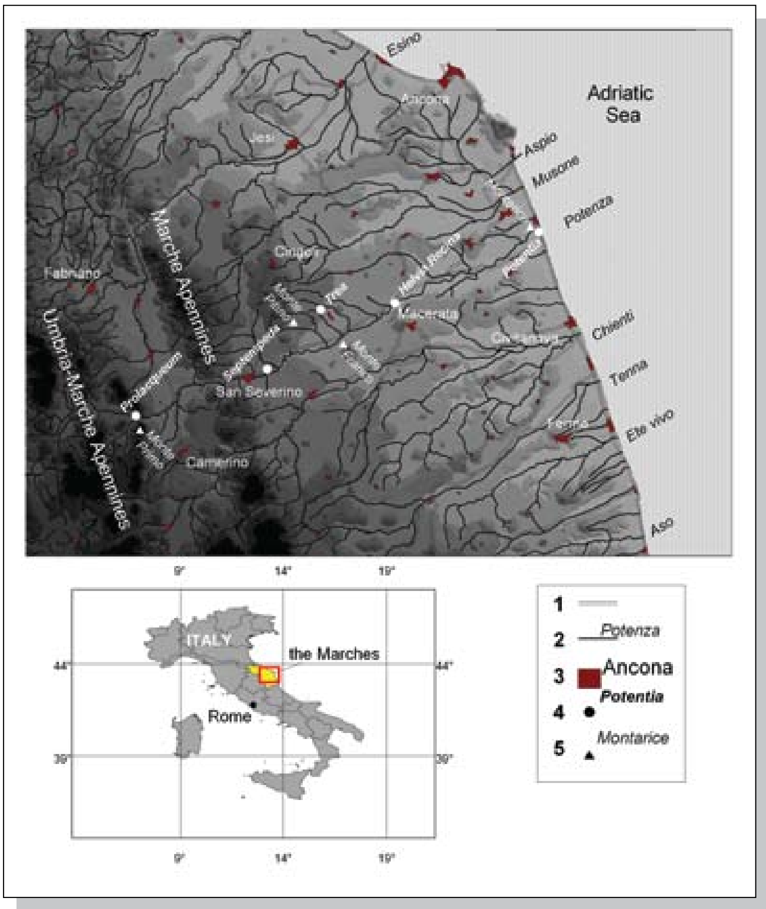


Figure 1 Location of the study area in Italy and the Marche region. Source data provided by the Ufficio Cartografia e Informazioni Territoriali, Regione Marche.

1 road network
2 streams
3 agglomerations
4 Roman cities
5 protohistorical sites.

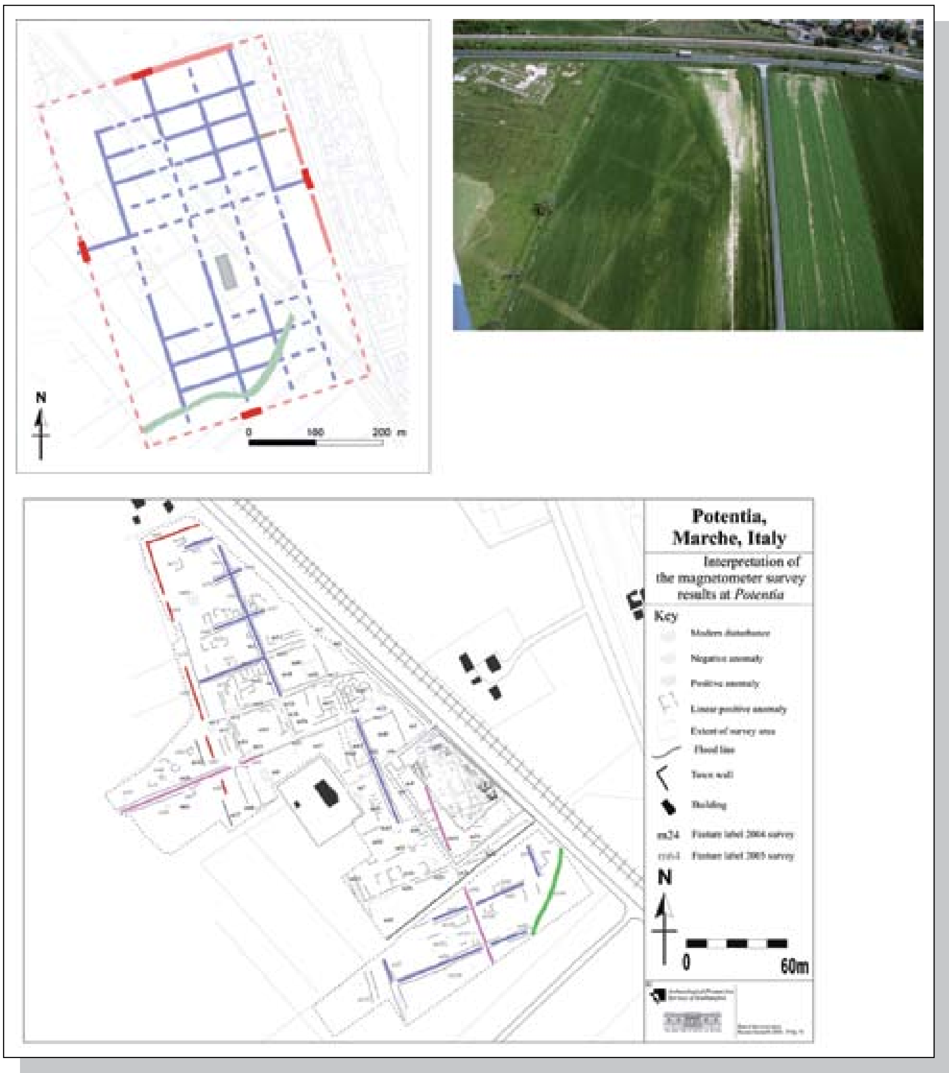


Figure 2

A Plan of Potentia extrapolated from aerial photographs showing the grid layout of the roads (blue), position of the gates and circuit walls (red) and indicating the location of the excavation of the monumental centre (grey). Source: Vermeulen et al. (2006).

B Oblique aerial photograph illustrating the erasing of the city wall evidence in the southeast corner.

C Interpretation of the magnetometer survey results at Potentia. For easier comparison with figure 2A, the same colour code has been applied: blue for roads, red for the circuit walls and green for the hydrographic disturbance. The linear features indicated in purple are the Cardo and Decumanus Maximus. Source: adapted from Hay (2005).

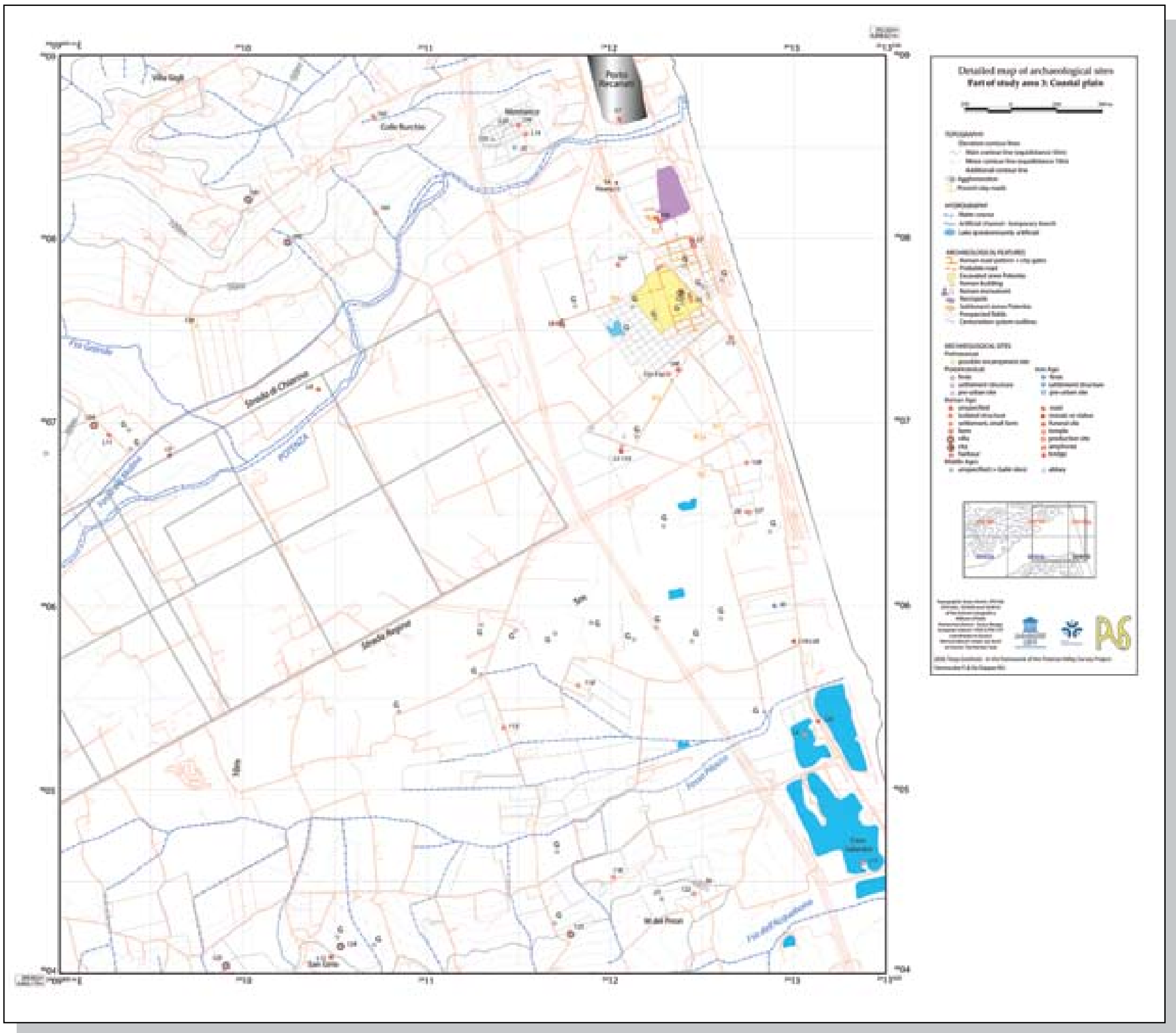


Figure 3 Archaeological sites in the coastal plain, on topographical background. Source data provided by the Ufficio Cartografia e Informazioni Territoriali and literature study.

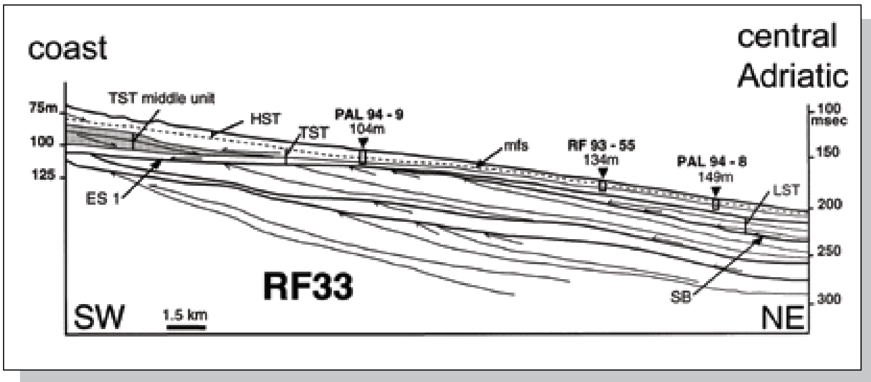


Figure 4 Geometry of the late Quaternary deposits in the western Adriatic Sea seen in the light of sequence stratigraphy: a falling sea-level systems tract (FST), a low-stand systems tract (LST), a transgressive systems tract (TST) and a high-stand systems tract (HST). Transect about 150 km south of Ancona. Source: Trincardi et al. (1996).

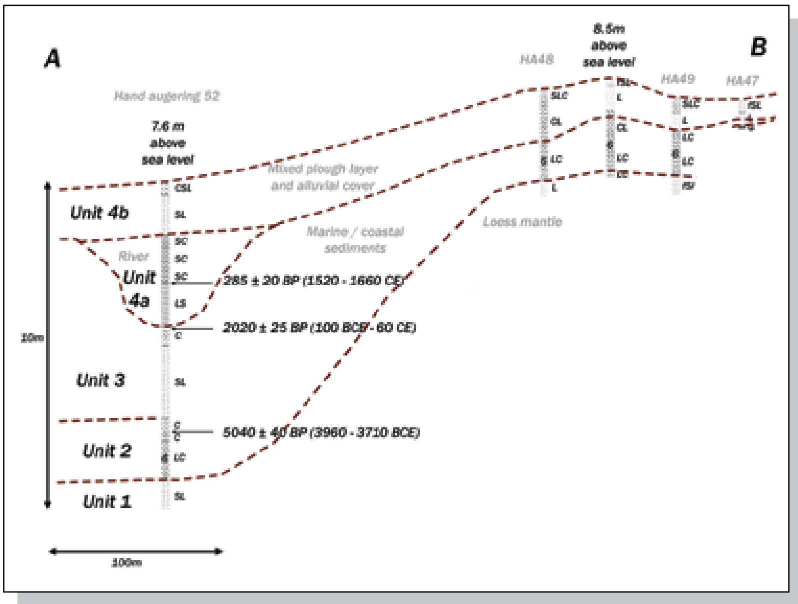


Figure 5 Transect crossing hand augering 52, evidencing the four main phases of coastal processes in the Potenza coastal plain. For the location of this transect and the hand augerings (HA), see figure 10.

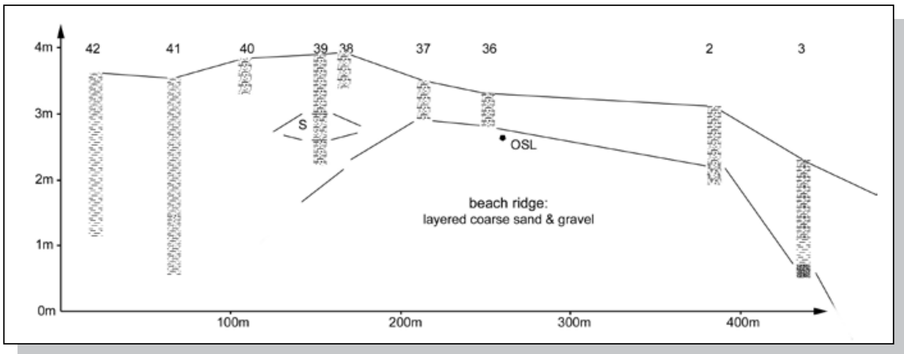


Figure 6 East-west oriented profile of the beach ridge upon which Potentia is situated, X = distance from arbitrary starting point, Y = altitude above sea level. The upper line represents the topographic surface, the lower line the surface of the beach ridge. The approximate position of the two OSL-datings in the beach ridge is indicated. These gave ages of 3.5 +/- 0.4 ka and 4.4 +/- 0.5 ka at respectively 15 and 30 cm depth below the top of the beach ridge. For the location of this transect and the hand augerings (HA), see figure 10.

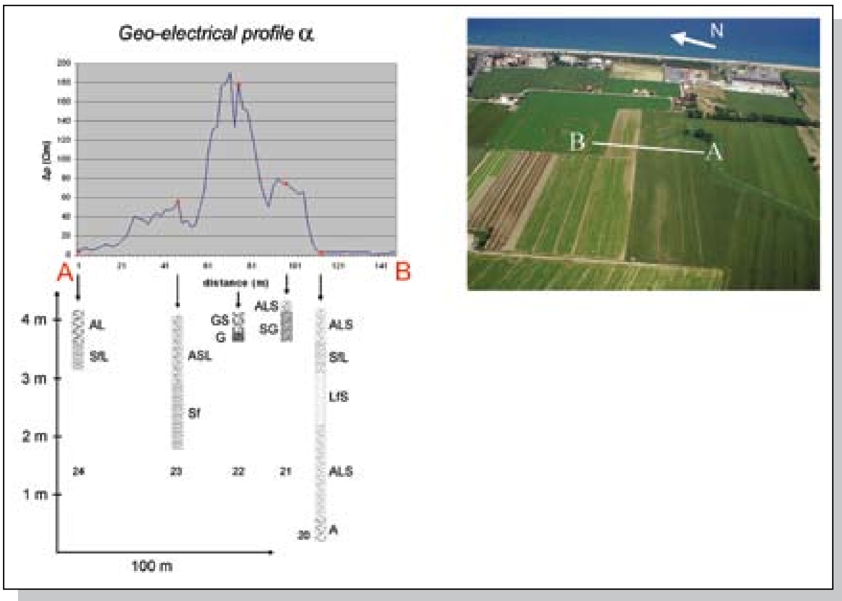


Figure 7 Geo-electrical transect α, type-section through palaeochannel I.

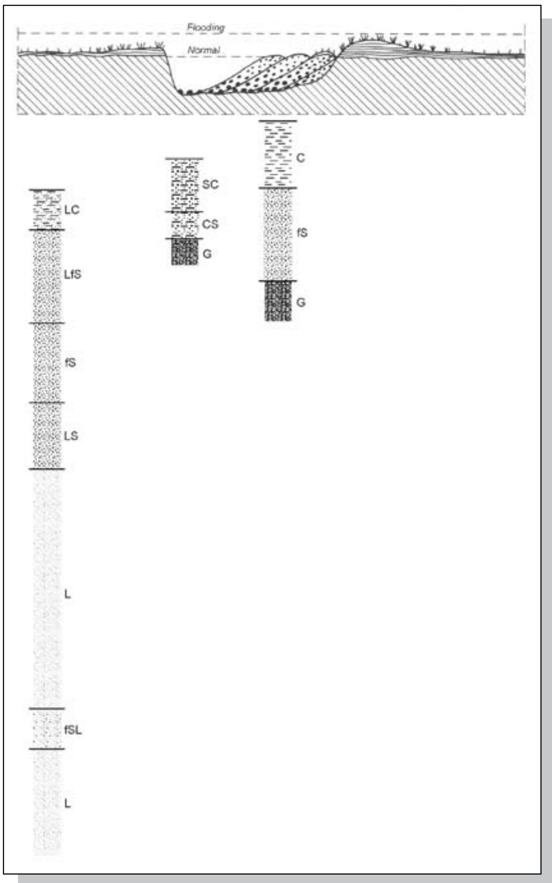


Figure 8 Augerings 8, 9 and 10, cross-sectioning through palaeochannel I, linked with a school-book example of a meander bend (translated from Pannekoek & Van Straaten, 1992).

Figure 9 The Casa del Arco site: A. Sketch of the situation; B. Photograph of Casa del Arco; C. Hand augering 1, executed near the alleged former Roman bridge, through sediments that are supposed to represent the *Flosis* (the Roman Potenza), palaeochannel II.

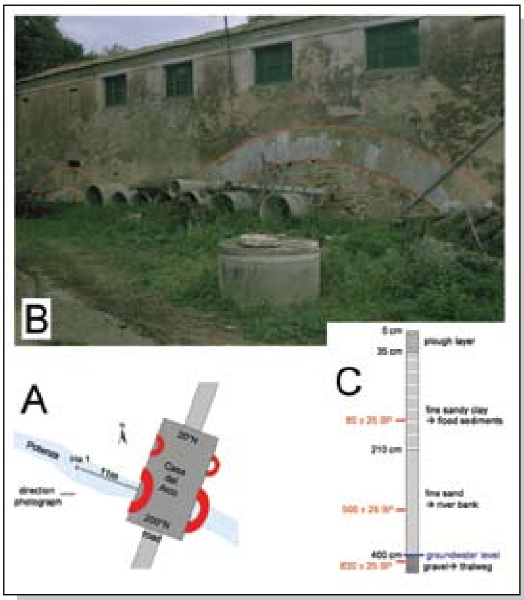
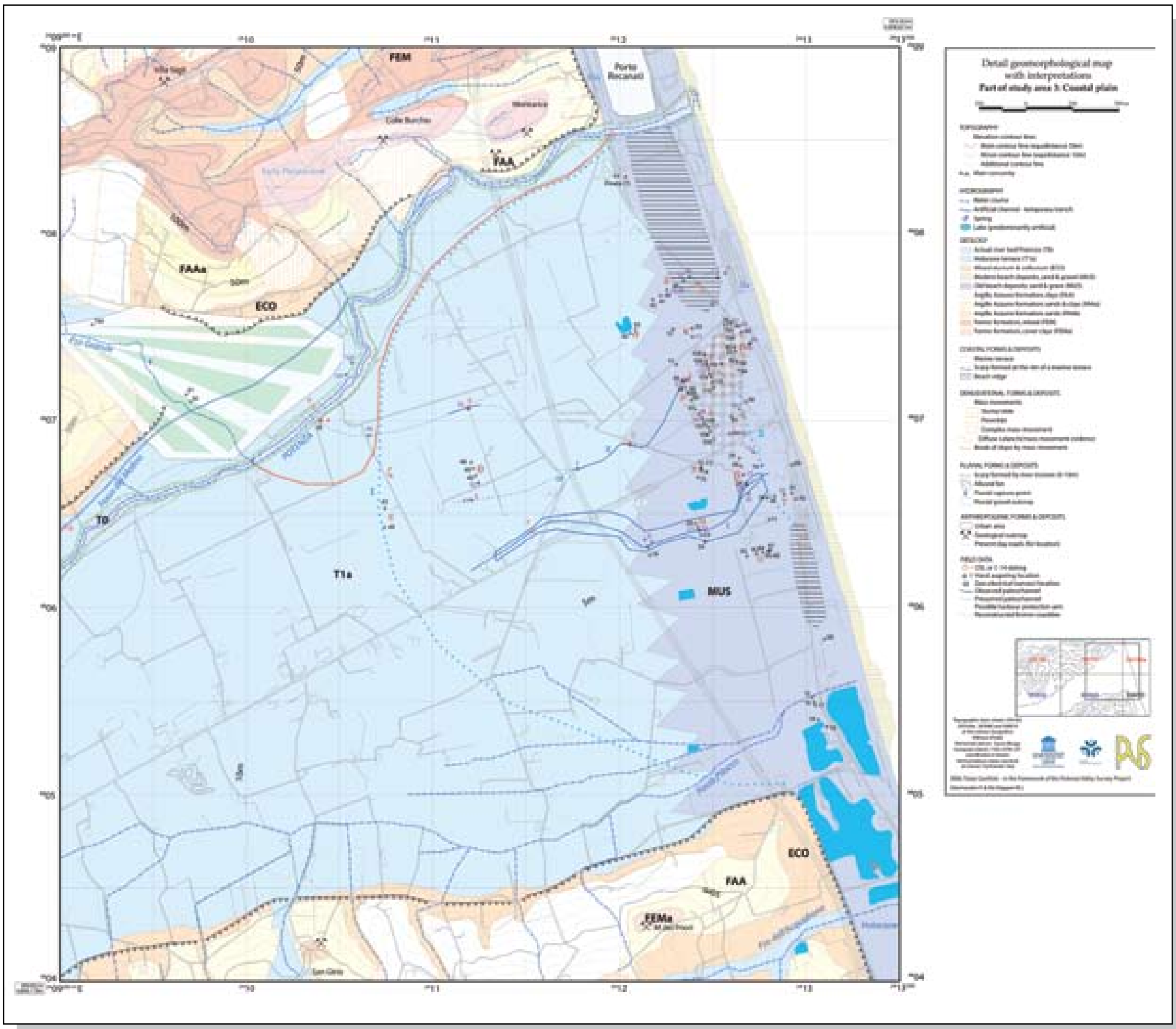


Figure 10 Geomorphological map of the Potenza coastal area with location of the hand augerings, geo-electrically measured transects, datings and possible palaeochannels.



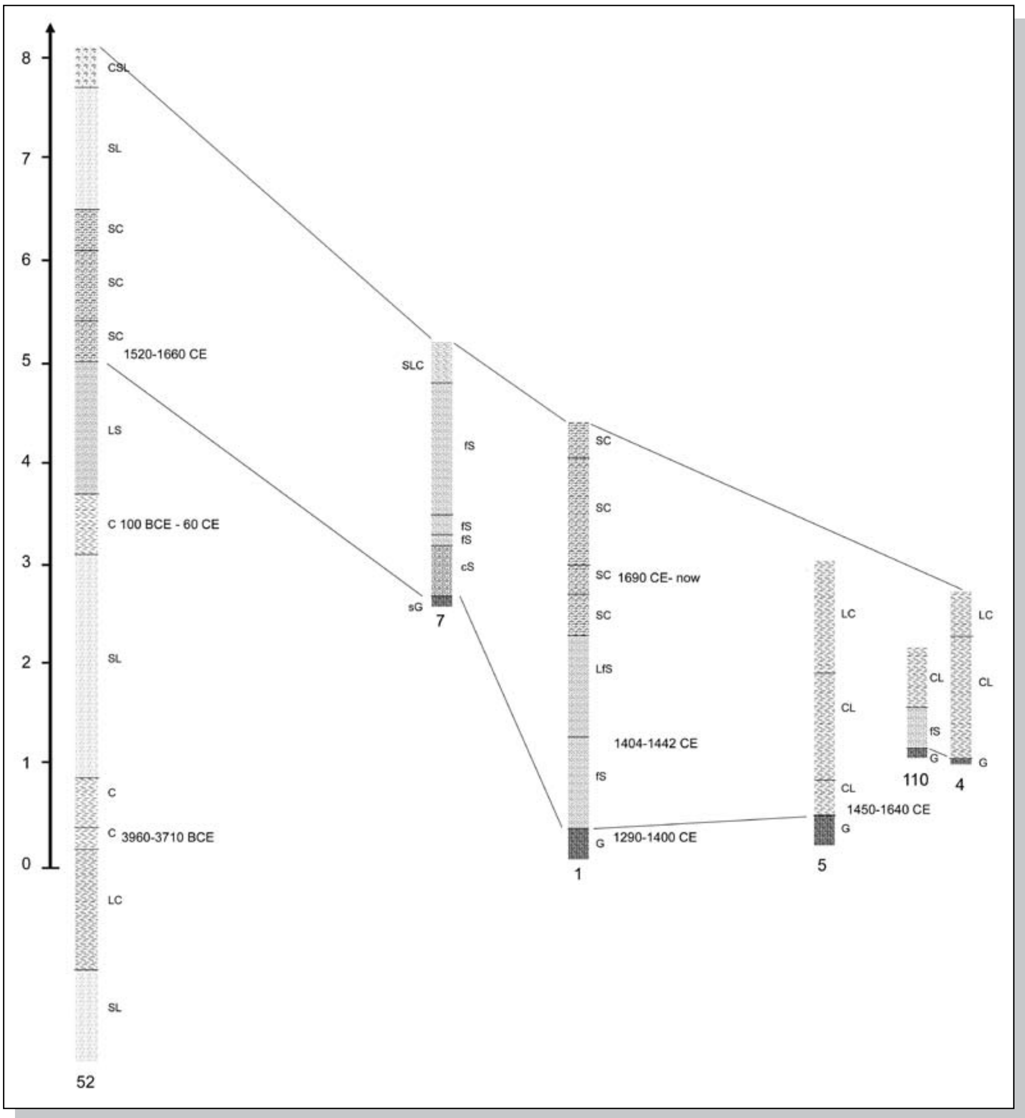


Figure 11 Cross-section through the hand augerings (52, 7, 1, 5 and 4) possibly representing palaeochannel II, the Roman and medieval Potenza.

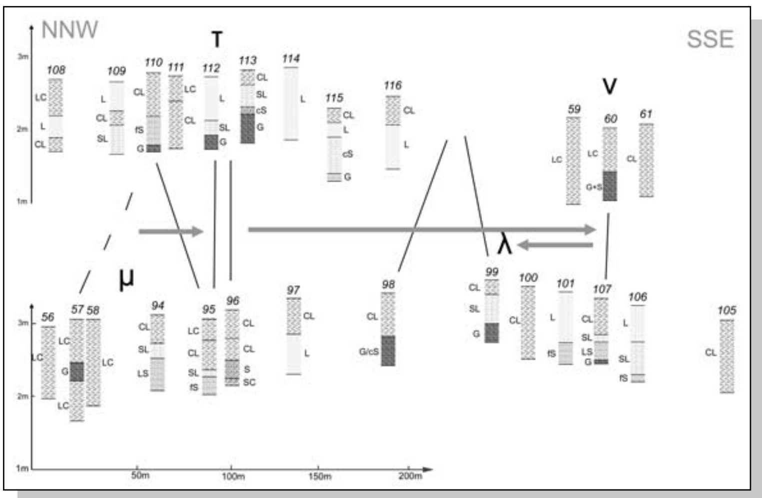


Figure 12 Cross-sections through the post-Roman channels in the deltaic debouchment zone of the former Potenza, as reconstructed by resistivity measurements and augerings.

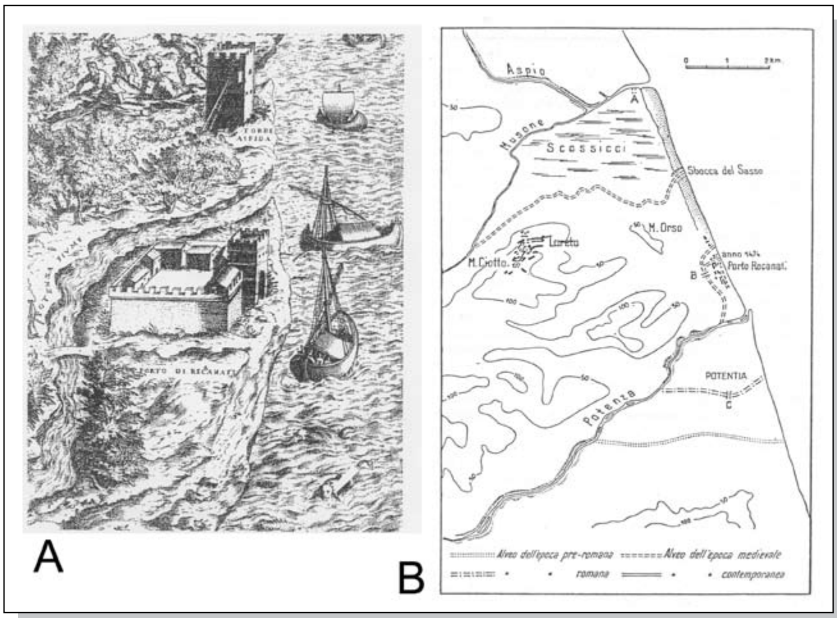


Figure 13 The diversion of the modern Potenza river around Porto Recanati, according to A. Baldetti et al. (1983) and B: Alfieri & Ortolani (1947).

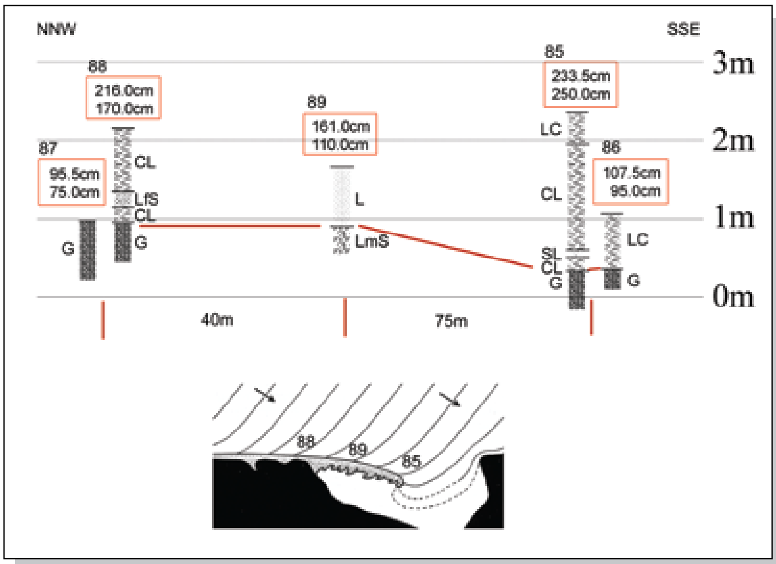


Figure 14 The hypothesis of a spit south of Potentia, illustrated with hand augerings (location see figure 10) and a textbook example (white = sea; black = land; speckled = spit), on which the locations of the augerings are added. Textbook example: Pannekoek & Van Straaten (1992).

GEOLOGICAL SETTING

From the pre-existing literature, the general dynamics of the Marches rivers in terms of erosion-accumulation balance and even coastline changes could be distilled. Thus this study concentrates on locating the features and on delimiting and mapping the main geomorphological processes in space and time, focused on the first millennium BCE and the first millennium CE.
On its way towards the Adriatic, the 88 km long Potenza river perpendicularly cuts a number of geological formations: two mountain chains constituted of Mesozoic folded limestone and marls, a gravely piedmont zone built up by dejection cones, and a hilly so-called periadriatic zone modelled in detritic Pliocene and Quaternary sediments (clays, sands and conglomerates; Servizio Geologico Nazionale d'Italia, 1967). The latter sediments form an east-facing, east-dipping monoclinal sequence, evidencing their development through gradual progradation and tilting generated by the Quaternary upheaval of the Apennines (most active during the transition from Lower to Middle Pleistocene, Ambrosetti & alii, 1982). The Potenza river valley still is subjected to regional epeirogenetic uplift, though comparatively slower at the coast. Subsequently, during the Middle and Upper Pleistocene, a staircase of climatic fluvial terraces developed on these sediments. During the Holocene, the sea level first rose to levels that caused marine ingressions in the Marches coastal plains and along the rivers some small-scale incisions of the Upper Pleistocene terrace took place.
In the mountainous parts of the Marches rivers, soil formation under thermophylous forest vegetation at the beginning of the Holocene was soon followed by a phase of travertine formation, which started around 7,000 calBCE and lasted until the onset of the Bronze Age, around 2,500 calBCE (Calderoni & alii, 1996; Cilla & alii, 1996; Cilla & Dramis, 1999). After the travertine phase, a drop in pollen concentration took place in the Apennines so that the swamps, which had dried up during the glacial period, returned. This event seems to be caused by deforestation, climatic causes (Cilla & Dramis, 1999) and/or human-induced factors (Coltorti, 1989), and coincides with the world-wide mid-Holocene climatic transition.
Along the middle reaches of the Marches rivers, five Holocene phases were distinguished by Coltorti (1989, 1997). Phases 5 and 4, respectively between the Late Glacial and the first half of the Holocene and from then onwards to the Roman Age or to the Renaissance depending on the river and location along the longitudinal profile in question, are both characterised by incision of meandering rivers, though during phase 4 their meander radius diminished. During these phases, up to 7 terrace steps were generated, each situated a few metres below the Upper Pleistocene terrace (Coltorti & Nanni, 1987). Phase 3 on the other hand was characterised by a gradual transition from meandering to strongly aggrading braided channels. This is associated with deforestation and subsequent rill and interrill erosion in the hills (Calderoni & alii, 1996),

though badlands are reactivated as well during this phase (Dramis & alii, 1982). Coltorti (1997) mentions that the coastline of the Marche region prograded seaward at a fast pace synchronously with phase 3, up to more than 500 m in some places. During the first half of the 20th century, known as phase 2, fast incision took place, probably because of a combined impact of the alberata cultivation system, straightening and fortification of river channels. At the end of the 20th century, phase 1, the incision was even enhanced by increased quarrying activities and introduction of check dams (Bisci & alii, 1992).

The evolution of the coastal areas is dominated by the Versilian transgression during the first half of the Holocene, forming a curved coastline characterised by an alternation of promontories and bays. Afterwards, the coastal evolution is "strongly influenced by fluvial dynamics" (Coltorti, 1989). This interaction and its impact on the archaeological evidence is the main topic of this paper.

ARCHAEOLOGICAL AND HISTORICAL EVIDENCE

In terms of archaeological evidence, the coastal area is by far the richest of the Potenza river basin. The most important sites are the Roman colonial town Potentia and the pre-urban hilltop site Montarice founded during the Bronze Age but also inhabited by the elite of the Iron Age Piceni culture.

The Montarice site is comparable in outlay to a number of important protohistoric hilltop sites along the Marchean coastline, such as Montedoro di Scapezzano near Senigallia and an Iron Age site near Pesaro (Boullart, 2006). In Bettini (1961) it is also mentioned that Vogel (1859) situated an ulterior Piceni site about 10 km inland of Montarice, at the location of present-day Recanati.

Potentia was founded in 184 BCE, as part of the colonisation plan of the Adriatic by the Roman Empire. Potentia was probably directly connected by paved roads with Numana to the north (and from there to Ancona, home of the Greek enclave), Ricina to the west, Pausulae to the southwest and Cluana to the south. The Via Salaria Picena would have run along the coastline, and this route was crossed by the offshoots of the Via Flaminia along the main river valleys.

Potentia is known as a portal city. However, the harbour had not been retrieved during the excavations of the city. Thus the harbour location was put forward as one of the main topics of geoarchaeological research.

A vast programme of public works at Potentia ensured the construction of a temple, an aqueduct, a sewer system, town circuit walls in sandstone blocks and a forum (Percossi Serenelli, 2001). The 56 BCE earthquake destroyed most of the structures. Excavations at the city revealed that the town centre was rebuilt during a period of bloom in the 3rd and 4th centuries CE. A crisis seems to have occurred in the 5th century, followed by a short revival, but from the 6th century onwards the number of inhabitants declined gradually, resulting in a total abandon of the city in the 7th century. Interpretation of oblique aerial photographs and geophysical investigations have aided the PVS team in retrieving the NNW-SSE oriented regular street pattern, the town walls that delimit an area of roughly 350 m x 500 m and two of the city's gates. Two phenomena occurred in the geophysical survey results: the magnetic signal became fainter towards the west, and a curvilinear anomaly cuts the southern part of the city (Fig. 2; Vermeulen & alii, 2006).

Along the roads leading out of the city, cemeteries and graves have been struck upon: one to the north dating from the Republican period, one to the west dating from the first century CE.

Just south of the city walls, at about 200 m distance from the present-day coastline (site 115, Fig. 3), a concentration of amphorae was retrieved.

To the southwest of Potentia, at a locality called Casa del Arco, 1.5 km south of the actual river bed, a Roman bridge is incorporated in a farm house. This bridge is supposed to have been part of the road connecting Urbs Salvia (Urbisaglia) and Pausulae (San Claudio di Corridonia) to Potentia. Both Alfieri & Ortolani (1947) and Moscatelli & Vettorazzi (1988) inferred a hypothesised palaeochannel flowing under this bridge.

Potentia's hinterland was very fertile: even Hannibal acknowledged the fertility of the Chienti and Potenza river coastal plains (Paci, 2001). Consequently, it is not surprising that Alfieri (1968) discovered evidence of a centuriation system in the alluvial plain, oriented WSW-ENE and composed of 10 double centuria, all squares with sides of about 700 m.

In the extreme southwest corner of the probable centuriation system, at locality Santa Lucia, a furnace for the production of – amongst others – vernice nera ceramics has been retrieved. This was not the only production site near the Potenza river: just south of the coastal plain, at the locality Casa Valentini (site 111), the wall of an in situ ceramics furnace has been reported and studied.

At the sites indicated by L8 and L11, road pavement stones have been discovered (at Casa Bilò and at Casa Lassandari; Percossi Serenelli 1985, 1995). These most probably indicate the further route of the Decumanus Maximus of Potentia. Towards the north, the prolungation of the Cardo Maximus was also evidenced. Firstly by remains of a Roman street in battered earth with remains of walls alongside, oriented north-south, exposed during works for a new bridge in 1946 (Percossi Serenelli, 1995; L7); secondly by the discovery of a very similar road flanked by funerary monuments, just north of Potentia (site 106). The tracé of the road southwards is less clear, though certain parts are visible as soil marks on aerial photographs.

During the field campaigns, most of the findings in the lower coastal plain were concentrated around Potentia, e.g. at sites 116 and 131, identified respectively as a road with funerary monuments and as a settlement zone of at least the first century BCE to the third century CE.

About 600 m to the SSE, two additional concentrations of Roman material (site 128) indicated another former settlement zone "along the Roman coastal road". Still 250 m more to the SSE, a possible early Roman production site is present (site 127), judging on the cooked clay and metal scorie, and the remarkably high density of amphore fragments and vernice nera. Next in line are a number of sites just mentioned but not described accurately by Galié (1987), lined up in WSW-ENE direction, in the southern half of the coastal plain, and a number of sites in the very south of the coastal plain, near the Fosso Pilocco rivulet.

COASTAL CHANGES

In this paragraph, the dynamics of the coastline and associated sedimentary deposits is discussed chronologically, starting at the onset of the Holocene. This interpretation is based on literature reviews, interpretation of maps and aerial photographs and an important body of fieldwork and laboratory results.

Off-coast evidence

The Holocene outset is attested well for the Adriatic Sea by the succession of submarine sediments (Trincardi & alii, 1996): the stepwise fall in eustatic sea level in the order of 120 m culminated during the last glacial maximum (LGM) of OIS2 and was followed by a much faster sea level rise after 17 ka ago. The late Quaternary deposits are consequently subdivisible into four units: a falling sea-level systems tract (FST), a low-stand systems tract (LST), a transgressive systems tract (TST, outset and start of the Holocene, the Versilian transgression) and a high-stand systems tract (HST, the end of the Holocene), see figure 4. The unconformity surface (downlap) between the TST and HST marks the time of maximum marine ingression.
The Holocene mud deposits contrast neatly with the underlying layer of Pleistocene residual shelf sand (FST), which was terraced at a depth of 40 m in the transect off the coast of Numana (Curzi, 1986), up to a distance of 50 km away from this coast. On the seaward slope of the Pleistocene terrace, chaotic deposits and a progradational wedge were deposited during the last glacial maximum (LGM), fed by the Adriatic rivers. The Holocene mud terrace (TST), deposited between 9.5 and 6 ka calBP according to Cattaneo & Trincardi (1999), is superseded by younger sediments of which the granulometry depends on the zone of deposition (HST). Thus, the littoral sands and gravels were supplied to the coast by rivers and by erosion of older deposits (predominantly landslide material, e.g. from the Conero massif), which are redistribu-

ted by littoral drift (Curzi, 1986). The Po delta and Adriatic rivers also supply calcareous muds, which in the Adriatic accumulated at an estimated rate of 1.7 mm/year to as high as 4.5 mm/year (van Straaten, 1971; judging on the specialised bottom fauna).
Nowadays, these granulometric zones are constituted predominantly by a littoral sand belt up to about 10 m depth, followed by a pro-littoral mud belt. The sand belt widens at the river mouths, and thins in correspondence to the interfluves (Dal Cin & Simeoni, 1993). Both wave action and marine sediment redistribution are dominated by wind activity. Although the most intense storms originate from the northern bora winds, the strongest wave action is more frequently associated with a southeasterly wind direction (Geyer & alii, 2002). The net sediment-redistributing force is southward, associated with the bora winds.

Coastal plain evidence

In the Potenza coastal plain subsoil, the above-mentioned granulometric zones have been present in shifting positions, regulated by variations in the rate of sea level change, similarly to what van Straaten (1971) proposed. When the rate of sea level rise was temporarily increased (to a rate faster than that countered by the uplift of the land), the sand supply to the beaches lagged behind, the beach barriers becoming severely breached. Thus the sea invaded the space on the landward side, shifting the coastline rapidly inland, up to 2 km in the case of the Potenza coastal plain, which is divided into two pieces by palaeochannel I, as will be discussed in the following paragraph.
Evidence for the incursion of the sea is mainly found in a section of 6 hand augerings roughly parallel to the present coastline, but about 1.8 km inland of it. The most important one of those is the 10 m deep augering 52 (Fig. 5), with from bottom to top:

- at 10 m to 9.1 m depth: loess-like sandy loam, pale grey with iron oxide stains, mixed with sporadic small gravel and secondary calcareous concretions;
- at 9.1 m to 7.9 m depth: loamy clay, pale grey, with sporadic calcareous nodules and shell fragments and at 8.25 m a distinct shell layer;
- at 7.9 m to 7.7 m depth: heavy clay, pale grey, with organic material inclusions and pockets of more sandy material which contain iron oxide nodules;
- at 7.7 m to 7.2 m depth: heavy clay, dark grey, discolouring to purple upon exposure to sunlight, with inclusions of organic material, which were dated at 5040 ± 35 BP or with within a 2σ-interval of 3960-3710 calBCE (KIA-25595);
- at 7.2 m to 5 m depth: sandy loam, pale grey to beige, fairly homogenous, with iron oxide stains;

- at 5 m to 4.4 m depth: heavy clay, dark grey, with abundant organic matter, dated at 2020 ± 25 BP or with within a 2σ-interval of 100 cal BCE to 60 calCE (KIA-25597), with dispersed very fine shell material, occasional loess puppets of maximum 5 mm length and reduction over the entire depth;
- at 4.4 m to 3.1 m depth: loamy sand, medium brown-grey, including the groundwater table at 4.1 m depth (on 28/09/2004);
- at 3.1 m to 2.7 m depth: sandy clay, medium grey, with organic material (charcoal) at 3 m depth, dated at 285 ± 20 BP or with within a 2σ-interval of 1520-1660 calCE (KIA-25596), with sporadic shell fragments and loess puppets and iron oxide stains in the root channels;
- at 2.7 m to 2 m depth: sandy clay, dark brown-grey, with pockets of rusty and black sand, occasional shell fragments (not dissolved) and dispersed gravel of up to 4 mm in length;
- at 2 m to 1.6 m depth: slightly sandy clay, pale brown-gray, with iron oxide stains and sporadic small shell fragments (1 to 2 mm large) and little weathered;
- at 1.6 m to 0.4 m depth: slightly sandy loam, pale brown to beige, homogenous in nature, except for a slightly higher clay content between 1.1 and 1.5 m depth; and
- at 0.4 m depth to ground level: clayey sandy loam, dark brown, with plant remains, gradually fading into the underlying layer.
- This succession can be subdivided into four facies units, with boundaries at respectively 9.1 m, 7.2 m and 4.4 m depth, which are discussed below, from bottom to top.

Pre-marine phase

The lowest unit, although here not absolutely dated, can be attributed to the late glacial period, before the marine ingression. Indeed, judging on the loessic nature of the deposits and the presence of secondary calcareous concretions, these deposits stem from an environment in which grinded glacial deposits have dried up and are redistributed by the wind from exposed situations to valley areas. This kind of environment is typical for interstadials and for the transition from glacial to interglacial periods. Analogous sediments have been retrieved on top of Monte Conero, in doline depressions, dated by means of included Mousterian artefacts, and covered by Holocene colluvial material (Chiesa & alii, 1990).

Marine phase

The second lowest unit is characteristic of the marine incursion known as the Versilian transgression. At the debouchment of the Foglia river, in the very north of the Marche region, this incursion is attested by clayey-peaty silt deposits of up to more than 30 m thick, dated terminus ante quem by a radiocarbon dating on elm remains of 10,090 ± 80 BP or 9,724 ± 224 cal BCE (CalPal Online Radiocarbon Calibration). During the marine ingression, cliffs at the end of both the northern and the southern interfluve deposit debris products on the abrasion platforms at their base. For example the Casa Valentini furnace wall, just south of the Potenza coastal plain, was built in deposits put in place 9,400 ± 1,600 years ago (GLL-040302; Vandenberghe 2005).

Beach barrier phase and fluvial infill

The second highest unit of augering 52 was installed at least some time after the radiocarbon date of 5040 ± 35 BP. The transition from heavy clay to sandy loam can be seen as characteristic for a shift from marine sedimentation to fluvial inputs, and appeared contemporaneous with the installation of beach barriers in line with the cliffs. At that time effectively the pace of sea level rise gradually slows down and is counteracted by the epeirogenetic uplift. Beach barriers can build up again, blocking off what started off as a kind of lagoon system with considerable terrestrial input, but subsequently became quickly infilled. Potentia is built on such a beach barrier, in which two OSL-samples were dated, respectively at 3,500 ± 400 years ago (15 cm below the top of the beach ridge; GLL-050308) and 4,400 ± 500 years ago (30 cm below the top of the beach ridge; GLL-050307). More southwards, another part of beach barrier evidence has been dated at 3,300 ± 500 years ago (GLL-050309; all OSL-dates Vandenberghe 2006). The beach barriers are easily recognisable, both by their stratigraphy of alternated imbricate fine gravel (2-10 mm) and coarse sand layers (each 1 to 5 cm thick) and by their geometry, with a steep seaward slope (about 90 m/km or 5°) and gentle landward slope (about 30 m/km or 2°). At first, it was assumed two generations of beach barriers were present, interspersed with a clay-filled depression. However, further research revealed that there is only one generation, with a top nowadays at 3.0 m above sea level, and about 250 m wide at the most developed part (Fig. 6).
The beach barrier evidence at present stretches from the northern end of the coastal plain to just southwards of Potentia where it ducks down, and a second part from just south of palaeochannel I (Fig. 10; see below) to the debouchment zone of the Fosso Pilocco. The remaining buried beach barrier narrows down towards the south, and the second part is situated closer to the present-day coastline. In practice, the beach barrier starts at the latitude of geo-electrical transect ş but more towards the coast, as in augerings 65 and 66 only a thinner layer of gravel (0.5 m) was retrieved. Considering the age of the barriers, it's unlikely that the coastline just literally prograded seaward, like Coltorti (1997) presumed. It's very likely that the fluvial inputs increased, but the image is rather one in which the coastal plain was barred from direct marine influence by beaches and the areas behind these were gradually infilled.
This phase is contemporaneous to phase 4a of Coltorti (1989, 1995, 1997),

characterised by incising meandering rivers along the middle reaches of the rivers, though with smaller radius than the phase 5 rivers. In the mountainous parts of the rivers, the travertine deposition diminishes drastically. The fluvial supply of sediments and on the other hand the relative sea level stillstand (because of equilibrium between the slow sea level rise and the counteracting Apenninic upheaval) ensure the gradual filling up of the coastal plain during this phase.

During the beach barrier phase, the abrasion platform at the base of the cliffs was terraced. In fact, large part of the beach barrier material probably originates from the redistribution of these sediments.

The deposition of heavy clay with high organic matter content between 5 and 4 m depth at augering 52 probably stems from a local depression in the landscape, judging on the very fine shell material (more likely belonging to terrestrial molluscs). The Roman age date might also imply that it was a pond, at the rim of the centuriation system.

Rivers and post-medieval floods

The highest unit of augering 52 evidences at first the installation of a fluvial channel during the Roman age, though the sandy nature instead of the normal gravel lag encountered elsewhere in the fluvial channels suggests that this augering 52 pierces through the riverbank sediments instead of the thalweg itself. The sediments above 4.4 m were radiocarbon dated between 1520 and 1660 CE (95% probability interval). Judging on their fineness and age, they can be attributed to the typical floodplain sediments of the post-medieval period. During this period, roughly from 1300 CE to 1700 CE, a thick layer of alluvial clays and silts was deposited in all coastal plains. In historical sources, this period is characterised by an increase of marshlands (even accompanied by malaria surges).

This is also confirmed for the Potenza coastal plain. A local depression filled with clay very rich in organic matter, observed in a long trench at about 4 km from the coast, was filled during the period 405 ± 30 BP or 1430-1630 calCE (2σ-interval; KIA-27606). Palaeochannel II, discussed below, is also covered by sediments of those ages, in numerous places.

The fluvial sands and gravels can easily be distinguished from the omnipresent clays and loams. Most of this clay/loam deck is caused by overbank floods, a minority originated as lagoon or swamp sediments. Indeed, the most frequently occurring mollusc species are Vertigo pusilla (Vertiginidae), Carychium tridentatum (Elobiidae), Vallonia pulchella (Vallonniidae) and Cernuella cespitum (Helicidae); complemented with more rare specimens of Pomatias elegans (Pomatiasidae), Ceciloides jani (Ferussaciidae) and Monacha cartusiana (Helicidae). All these species hint at a terrestrial nature of the deposits, albeit that their habitat diverges from dry rock locations over forests and moist grasslands to –still some– marshlands (Goethals & alii, 2006).

The river installation coincides with phase 4b of Coltorti (1995), a phase characterised by geomorphological stability, with meandering rivers inland and incision of the mountainous parts of the rivers. The post-medieval phase, on the other hand, was attributed to a new phase, phase 3 (Coltorti 1995, 1997). During this phase, characterised by strong accumulation, the river regimes changed from meandering to anastomosing in the middle and lower parts of the rivers. This accumulation would have been triggered by deforestation and subsequent soil erosion and increased badland activity. The evidence found in our study however contradicts the statement of Coltorti (1995) that the cliffs were only then transformed into inactive cliffs by the presence of a terrace at their base.

FLUVIAL CHANGES

The most striking resemblance between the Marchean coastal plains is the fact that the rivers have not always been in the position they are now. They have almost all changed their course over time, as is evidenced in their subsoil of thick clay bodies intercalated with lenses of coarser sediments. This change of course probably was not gradual, but rather instantaneous, by avulsion. Flooding events interfered with branching and diversion of the Potenza river in its coastal plain: during peak flows, a barrier could be overcome and a new river course was created. The new location, in theory, will generally be the lowest path on the floodplain which is not obstructed. According to Brown (1997), in systems dominated by overbank deposition this will often be at the floodplain edge or the edge of the channel belt (as these are often the topographically lowest places). However, especially in this region, human interference plays an ever increasing role in this process.
In this paragraph, the subsequent positions of the Potenza river in its coastal plain, and the most plausible causes for their emergence are discussed on the basis of literature, interpretation of aerial photographs and geomorphological field work data, including hand augerings, geo-electrical profiling and mollusc analysis.

Palaeochannel I

On the vertical aerial photographs of the Istituto Geografico Militare d'Italia, a pale trace of about 100 m wide and 3.5 km long is clearly visible in the very centre of the coastal plain. On the more detailed oblique low-altitude aerial photographs, the trace exhibits an anastomosing pattern (Fig. 7a). On the field level, abundant gravel crops out at the palest locations, though the delimitation is more difficult from this point of view.

The palaeochannel hypothesis is amply confirmed at transect α (Fig. 7a), a type-section, which exemplifies the lateral extension of the various sedimentation zones by means of plateaus in the graph of apparent resistivity (Fig. 7b). Hand augerings permitted to correlate the resistivity values with a textural range: in the central 20 m, gravel is present, evidencing the former thalweg; after a transitional zone of about 10 m on both sides, two sandy zones of 20 to 30 m wide each are present, interpreted as the river banks; and the surrounding clays represent the alluvial floodplain sediments.

Inland, evidence of the palaeochannel has been retrieved in hand augerings 8 to 10, be it that in this transect, the profile is more asymmetric. Indeed, augering 8 in the centre revealed the thalweg as by gravel in a sandy matrix from 60 cm depth onwards (and abundant gravel in the cover layers). Augering 9, situated 44 m to the north, probably evidences the river banks by its fine sand layer upon gravel, covered by a clay layer; while augering 10, situated 44 m to the south, already displays pure floodplain sediments (loams and clays). However, this asymmetry can be perfectly explained as a local bend in the channel, where lateral accretion surfaces build up at the inner bend and erosion takes place on the outer bend (the cut bank, Fig. 8).

Towards the coast, the results are less straightforward. The geo-electrical signature of transect β is misleading for textural interpretation: at the part with the most gravely and sandy subsoil sediments, overall low resistivities were measured. However, considering the vicinity of the coastline, we can assume saltwater intrusion, which would explain this phenomenon of inversed resistivity. In that case, the northern limit of the debouchment zone of this palaeochannel can be assumed to be situated at the resistivity decline, between augerings 28 and 29. Towards the south, no trace of fluvial gravel was retrieved in geo-electrical transect γ (except at more than 2.5 m depth, which is too deep to be linked to palaeochannel I) nor in augering 71. Thus, instead of forming a broader delta zone, the palaeochannel gains only little in width towards its debouchment zone, limited to a restricted space north or west of the aforementioned locations.

It was first assumed that this channel was younger than the one passing at the Casa del Arco site (palaeochannel II, discussed below), because the clayey-loamy cover layer is considerably thinner and consequently the channel is much more visible. However, the thick gravel beds of palaeochannel I are dated with Optically Stimulated Luminescence (OSL; Vandenberghe 2005) at an age of 3,600 ± 400 years ago, contemporary to the top of the beach ridge on which Potentia is built. Thus, it can be considered a kind of embryonic river terrace, not too outspoken because of the vicinity of the coast.

The alignment of archaeological sites mentioned by Galié (1987, Fig. 3, sites marked "G") might attest of a tributary of the Fosso Pilocco. In any event, these sites are separated, as the terraced palaeochannel I subdivides the coastal plain of the Potenza river in two parts with separate geomorphological evolution

Palaeochannel II and the harbour

The thalweg of this palaeochannel runs under the alleged Roman bridge at the Casa del Arco site. Effectively, a hand augering (Ha 1; Fig. 9) revealed a fluvial fining upward profile with at the base (below 400 cm depth) gravel and coarse sand; covered by fine sand and silts (between 400 and 210 cm); and topped off by sandy clays (upper 210 cm). This indicates sediments which were transported and deposited in a river channel with decreasing water velocity, finally sealed off by a clayey cover of flood sediments.
It was first hypothesized that the Potenza river flowed here exclusively during the Roman period. However, radiocarbon dating upon some charcoal fragments retrieved in the base gravel of the river at 420 cm depth (= 50 cm above modern mean sea level) indicated that this course was still active until 630 ± 25 BP (KIA-19509), i.e. calibrated with 95% certainty between 1,290 and 1,400 calCE (2σ-interval). Two younger radiocarbon dates higher in the profile confirmed the rather undisturbed nature of the sediments: the fine sand at 310 cm depth contains charcoal from the period 1,402 to 1,442 calCE (2σ-interval, KIA-19508), while the real flooding was attested by a charcoal fragment in the clays at 140 cm depth, which was attributed an age of 80 ± 25 BP (KIA-19504), or calibrated between 1810 and 1920 CE (2σ-interval).
The inland continuation of this channel is probably evidenced in augerings 7 and marginally in augering 52 (Figure 10; see 5.3). The slope of this palaeochannel amounts to about 4 m/km (Figure 11), which is about the same as the slope of the surface of the coastal plain nowadays. However, a caesura is present in the longitudinal profile, for as far as it could be reconstructed: an abrupt decrease in slope angle near Casa del Arco. This hints at a deltaic debouchment zone of bifurbicating channels, where the sediments transported by the rivers are deposited and coastal processes interfere, rather than a straightforward channel. Although it was at first thought that hand augering 5 evidenced a continuation of the "Roman" palaeochannel II, this is most probably not the case: the gravel is present in an elevated topographical position, and the cover-sediments do not present a fluvial fining upwards profile. Consequently, it is more likely that the gravel of hand augering 5 is either a kind of base gravel of an embayment, possibly hosting the harbour of Potentia; or one of the first channels in the embayment, later bended towards the north slightly, erasing the southeast corner of the city walls (Fig. 2). The age was confirmed by charcoal fragments in the clayey loam sediments immediately covering the gravel at hand augering 5, which were dated at 355 ± 30 BP or with 95% certainty within the interval 1450 – 1640 CE.
On a number of oblique aerial photographs, such fluvial channel patterns do appear (Fig. 10). Hand augering 4 was executed right in the middle of such a channel. However, these fluvial channels are younger than the one at Casa del Arco, as they are located higher, as is illustrated in Fig. 12. At hand augering 110 the gravel is situated 130 cm above sea level, while in hand augering 4 it's

at 110 cm above sea level (covered with 165 cm of finer sediments). The fluvial bed of palaeochannel II on the other hand is situated only 50 cm above sea level at the Casa del Arco site. Consequently, augerings 4 and 110 cannot belong to the same palaeochannel II. The fluvial, deltaic pattern visible on the aerial photographs is thus to situate in a later period.

Considering the gradual southwards movement of the delta channels and the depth (60 cm above sea level), the channel attested in hand augering 5 must have been one of the first in use. Afterwards, the position shifted southwards through the mentioned positions, probably in a controlled deltaic way, and finally, possibly abruptly, moved northwards again, even bending towards the last recorded position (IIa, Fig. 10), erasing the southeast corner of the Potentia town structures, possibly under influence of coastal processes. Traces of this last position have been found on low-altitude aerial photographs as well as during the magnetic survey (as a positive anomaly, indicating gravel presence; Fig. 2).

Following these findings, the harbour should be looked for at or below the present sea level, quite deep below the topographic surface (2.5 m at hand augering 5).

All through Roman age and till the end of the medieval period, the Potenza river is said to have been navigable. This is also argumented by Percossi Serenelli (2001a) on the basis of the calcarenite which served for the construction of the temple podium. This rock, emanating from the middle to lower reaches of the Potenza valley, would have been transported on water.

Thus, the change in fluvial dynamics, with the palaeochannel II suddenly depositing large amounts of fine sediments in the coastal zone and the deltaic system setting in, took place only at the advent of the "modern era" (1400 CE and onwards). This concurs with the findings of Buli (1994) and Coltorti (1991): "because of the long-lasting meandering regime along the middle and lower reaches (until the 15th century), the beach ridges at the river mouths would have formed probably only after the 15th century when increased sedimentation took place". Although it was not the increased sedimentation that lead to the formation of beach ridges, and the beach ridges in any event predate this period, the change in regime which they mention did definitely occur, and it was this sediment that must have filled the lagoonal-marshy area behind the beach ridges. On the other hand, Coltorti (1997) mentions a transformation of the river regimes from sinuous incising rivers to anastomosing, aggrading rivers already during the Roman age in the Marche region. For that matter, this phenomenon is attested in the entire Mediterranean basin (Bruneton et al, 2001; Marchetti, 2002).

During the filling-in of the lagoon, as suggested before, small rivulets or maybe even ditches kept flowing, into different positions. This took place in the form of a delta system, extending fan-like to a maximal length and width of about 750 m. Indeed, within this zone, the geo-electrical measurements and accompanying hand augerings have evidenced a number of the superficial delta channels which were partly visible on the aerial photographs (Fig. 12), progressively more southward. However, the geometry leads to assume that the channels are not all simultaneous. Next to the aforementioned channel attested by hand augerings 110 and 4 (channel at respectively 130 and 110 cm above sea level), a younger one passes at hand augerings 112 and 113 (at 190 and 220 cm above sea level) and a next, even younger one is evidenced at hand augerings 98, 99, 107 and 60 (respectively 280, 300, 250 and 220 cm above sea level).

Linking both with the actual findings, the most plausible explanation is that the river indeed started carrying more sediments during the Roman age, but that is was only later, during the Renaissance period, that the delta system could develop, following a change in relative sea level and/or maritime regime, cancelling out the maritime erosion factor in the erosion-accumulation balance. In this way, by invoking marine changes, it is also explained why the phenomenon occurred along the entire Marche coast and beyond.

Interconnections

The connection of palaeochannel II inland can stem from two directions: either from the north (from augering 52; Fig. 10; case A), or from a separate course from the west or south (from augering 47 or palaeochannel I; case B).

In the case of a northern origin (case A), palaeochannel II can have been in use only from the Roman age onwards. In the profile of hand augering 52, this was evidenced by the loamy sand which is the presumed thalweg/riverbank sediment, overlying a marine or flood clay layer dated at 2,020 ± 25 BP (KIA-25597) or the interval 100 BCE – 60 CE (2σ). Consequently, the installation of the palaeochannel crossing hand augering 52 would predate the middle of the Roman age.

However, a superficial gravel lens present at augering 47, and to a lesser degree at augering 50, supports case B. This can have only a fluvial interpretation, be it the remains of an embryonic river terrace or part of a palaeochannel. To clarify the eventual possibility of the interconnection, a transect west of augering 7 could be measured geo-electrically, but it is not even sure whether satisfying results would be obtained with geo-electrical measurements (with the configuration now applied), considering the large depth of the evidence of this palaeochannel under the surface: 400 cm at augering 1 and 250 cm at augering 7.

A connection starting at or near augering 52, which probably pierces the riverbank sediments, is possible. The most likely scenario in that case would be that the connection would pass just south of augering 52. Indeed, when comparing the profiles of augerings 5, 1, 7 and 52, the remarkable resemblance in stratigraphy and sedimentology (fining upward, gravel or coarse sand at the bottom) on the one hand, and the strikingly matching abandonment dates on the other hand, leave to suppose that all these channels were part of the same

system, at least during their final period of existence. A complementary argument is found in hand augering 44, where a typical fining upward profile was found, with at its base fluvial, rounded gravel. Thus the channel would lead from hand augering 44, south of augering 52, to augering 7.
In this most likely composed case, palaeochannel II was installed somewhere after 3,600 ± 400 years ago (the OSL-date of palaeochannel I) passing through augering 47 (case B). Subsequently, the source of water either remained, or was redirected from the north, just south of augering 52 during the Roman age (case A). Finally, the channel was abandoned in the late medieval period, probably somewhere in the modern era (after 1400 CE). The curvilinear anomaly mentioned in the archaeological introduction (Fig. 2), which erases part of the wall and street pattern of ancient Potentia, show the typical pattern of an anastomosing river. This palaeochannel (IIa on Fig. 10) would date from the very end of the infilling (Fig. 12), during the late medieval period.

The present course

The present course of the Potenza river is situated in the extreme north of the coastal plain, grazing the base of the hills composing the northern interfluve. Since all rivers in the Marche region show a marked asymmetry, their thalwegs being displaced to the south, with a well developed river terrace sequence on their left banks and a stunted terrace sequence at their right banks, this is quite a remarkable position for the Potenza river near its debouchment. Only the Musone river is equally displaced to the north in its coastal plain. In the case of the Musone, however, ample passages point to a deliberate rerouting of the river for land reclamation (Alfieri & Ortolani, 1947). For example, the abbey of Santa Maria in Potenza, with landed properties and dependent on the Cistercian order at Chiaravalle di Fiastra (founded in the 12th century CE), was located less than 1 km southeast of Potentia.
In the late Middle Ages and early Renaissance, large tracts of land in various Marchean coastal plains were reclaimed (Cencini & Varani, 1991; Nanni & Vivalda, 1987). Less sources mention the Potenza, but Buli & Ortolani (1947) found a letter of pope Gregory the 9th (°1170 – †1241) addressed to the inhabitants of Porto Recanati, ordering them to arrange a confluence between the Potenza, Musone and Aspio rivers. Furthermore, the construction of a harbour at the confluence was planned. The project was abandoned in 1474 after long periods of inactivity, but still this document illustrates the ideas that occupied the local government at that time. All these arguments add up to the assumption of a high degree of human intervention in the rerouting of the Potenza river. Note that this period coincides with a period of large-scale landscape planning, spurred by increased population numbers. Famous examples include the channelling of the Arno river in order to make it navigable from Florence to Pisa (a project taken up by Leonardo Da Vinci), and the draining and reclaiming of the malaria-infested Pontine marshes, which remained in the planning phase until 1930.

The field work corroborated the abovementioned historians' hypothesis of artificiality. Firstly, at a distance of about 3 km from the coast, the morphology of the river bed changes abruptly, from a broad bed with abundant gravel bars in the west to a narrow, deeply cut, channel-like bed to the east. Moreover, at this location, the channel starts to break through an alluvial fan of the Fso Grande, a left bank tributary of the Potenza river. This alluvial fan surface is 2 m higher topographically than the alluvial plain surface just to the west.
A second argument is presented at hand augering 35, executed just south and still within the embankments of the actual Potenza. In the stratigraphy, a sharp boundary is present at 170 cm depth. Below, a clayey layer of about 20 cm thick with abundant ceramic fragments is present, radiocarbon dated at 1860 ± 25 BP or with 95% certainty within the interval 80-230 CE. Above, loamy sand sediments with some gravel inclusions occurred. Consequently, it can be deduced that this location was settled during the Early Roman Empire, and that only afterwards the river broke through. The coarseness of the sediments just above the caesura indicates that the first floods of the river must have been rather energetic, as if engendered by a sudden breakthrough.
Subsequently, the Potenza river was most probably (partly) diverted towards the north in its final 500 m before reaching the present coastline. According to Alfieri & Ortolani (1947), this course existed at the "end of the medieval period" (Fig. 13), and is evidenced by an epigraph on a bridge in Porto Recanati which states "Arcus hic est pars pontis Potentiae veteris dictae le Fiumarelle" (="this arch is a part of the bridge over the old Potenza, the so-called Fiumarelle"). However, the date of this inscription has not been retrieved; and the route of the supposed course is now situated under the city structures of Porto Recanati, which renders it impossible to still retrieve any evidence now.

IMPACT ON POTENTIA AND THE SITES IN THE COASTAL PLAIN

The harbour of Potentia

As mentioned, all the evidence found up till now does not contradict the hypothesis of the Roman harbour being located south of Potentia but rather confirms it. The body of evidence does not strictly exclude all alternative hypotheses (such as the one of Galié 1987, about the harbour at the mouth of the Fosso Pilocco) and mean that this was effectively the harbour, but the arguments all point in this same general direction.
This position would also be very suitable for natural protection, since starting from the beach barrier, spits would be able to develop, which could serve as natural protection and docking wall for boats. At first sight, such spits would be very likely at the location where the concentration of ampho-

rae fragments was found. In the vertical section represented in Fig. 14, an imbricate gravel deposit was present starting just south of Potentia's southeastern corner, wedging out southwards over a length of 110 m. In the middle, the gravel is substituted by loamy medium sand deposits, which is not unusual for spit deposits.

However, the altitude of the gravel surface is insufficient: 95 cm above present sea level in the north, and 35 cm above sea level in the south of the cross-section. At augerings 1 and 5, the gravel is at 71.5 cm and 61 cm above present sea level. So the supposed harbour floor in between, just south of Potentia, does slightly rise towards the sea, offering not so much of a protecting wall, but rather a shell-shaped morphology with as seaward rim a slightly elevated sand/gravel bank of maximum 50 cm.

Off coarse, the later fluvial interaction of palaeochannel IIa might have levelled and flattened part of the spit, which can explain the sand instead of gravel in the centre of the cross-section. But overall, it seems unlikely that such a large shell-shaped depression would have been present, just south of the city, at minimum 1 up to 2.5 m below the beach ridge on which the city was constructed (Fig. 6), without being used as a harbour.

Thus the presumption made by the archaeologists on sites 116 en 131 that these were "possibly linked with activities along the river bank near the probable harbour of the city" is still likely considering the geomorphological evidence.

On the other hand, the sea level would have influenced greatly the practicability of the harbour, since during sea level lowstand the harbour floor would become dry. However, the sea level changes on the Adriatic side of Italy during the Holocene have only been studies in the north, around Venice and Trieste, and in the south, from the Gargano peninsula onwards. The central Adriatic remains largely unstudied, mainly because of the lack of physical evidence (such as growth of beach rocks, notches in rocky coasts, etcetera). So there is no means of assuring the level, especially when it comes to a precision level of less than 1m altitude.

Roman river management and roads

The position of Potentia exemplifies the need for interdisciplinary geoarchaeological research. Historian Galié (1987) supposed that the presence of important cities would necessarily imply that the rivers were channelled and embanked. This is not the case, as Potentia is situated on a beach ridge, id est on a naturally elevated, secure position.

However, on the other hand Galié does have a point in the necessity for embankments on the north side of the Flosis (the Roman Potenza river) in its last few hundreds of meters before reaching the debouchment zone a.k.a. harbour in order to permit a well protected road from Casa del Arco to Potentia. Not in the Roman age, since although the contemporaneous expansion of the Pontine marshes near Rome suggest a wetter climate, this was not the case. The Pontine marshes were human-induced; the river levels in the Marches region were higher than today and flooding could occur, but not to that extent that overall marshy conditions should be assumed in the coastal plains during the "Roman warm period" (cf. Ortolani & Pagliuca, 2000). It was only later, when the embankments were not cared for any more and the climate worsened, that the rivers could overflow and bury parts of the city structures, as is evident in Fig. 2. The major sediment decks date from the late medieval and early post-medieval periods (1400 to 1600), seemingly a period of high environmental and social stress, with pests and famine went hand in hand with floods and mass movements. Historians (Galié, 1987) found many scriptures documenting marshes in those periods, near the debouchments of the rivers Tronto, Chienti, Tenna, Esino, Potenza and Musone.

As mentioned, there is supposed to be a coastal road (R1 on Fig. 3), the Via Salaria Picena, part of the road connecting Brindisi with Rimini. Some cross-sections were measured geo-electrically and checked with augerings in order to establish whether the coastal road would have led parallel to the coastline, on the beach barriers and crossing the delta in between the Potentia beach barrier and the one starting again about 1 km to the south, but such was not the case. A road closer to the coastline than the hypothesized R1 cannot be excluded per se because the modern urbanisation prevents geomorphological research, but is quite unlikely, given the extension of the debouchment zone and the probability that the coastal line was situated about 300m inland in this zone (cf. fine sediments in geo-electrical transect γ).

The most logical explanation would be that the road bypasses the debouchment zone of the Potenza river, or the Flosis as it was then called, by going inland to the Casa del Arco site where the crossing is easier. As a matter of fact, from the Casa del Arco site up a modern road leads southeastwards, possibly constructed on an earlier road. In that case, evidence would be expected in the prolongation of this road (Fig. 3, R2), but geo-electrical transect π did not bear any hints of gravel presence, and neither did augerings. In transect β, the presence of gravel in several of the augerings suggests that this is not road gravel.

On the other hand, another white rectilinear trace (Fig. 3, R2a), most likely reveals a former road: at augering 54 alongside the trace, no gravel was present in the profile; while at augering 55 in the trace, a gravel layer has its top at 80 cm depth below the present surface. This road leads parallel to R2 and possibly crosses augering 107, although this can as well have known a fluvial origin. However, how and where the river Flosis (Potenza) was crossed then, is not clear.

The road leading from the Casa del Arco site to the south gate (Fig. 4, R3) of is evident except for the last 200 m to the south gate, at least on low-altitude aerial photographs. It concerns a provisory road of about 25 cm thick gravel (at 60 to 85 cm depth below the surface or 2.2 to 2.5 m a.s.l.), resting directly on the loamy clay deck. The remaining 200 m was in all probability erased by the last of the post-Roman delta channels (cf. paragraph 5.2).

For the road leading WSW wards inland from Potentia (Fig. 3, R4), several arguments arise: firstly by the mere presence of a west gate in the town of Potentia, secondly by remains of a funerary monument at the site called Torraccio (figure 3, L6), thirdly by part of the hypothesized route being in use by a modern road, and fourthly by the road pavement stones at sites L8 and L11, directly in line.

Finally, the road north of Potentia (Fig. 3, R5) is substantiated by the necropolis and funerary monuments (Fig. 3, site 106 and necropolis polygon) and site L7.

For both roads (R4 and R5), no physical research was conducted. In any case, given its position on a gravel beach barrier, it would be very difficult if not impossible to retrieve road R5, and excavations of the necropolis and surroundings were little documented.

The changes in city layout

As mentioned, the outlay of the city has been studied through excavations, aerial photograph interpretation and geophysical investigations (figure 2). However, the presence of evidence does not imply that all city structures were present already when the city was founded (184 BCE). Other than the rebuilding of parts of the city after the 56 BCE earthquake (the only one of that magnitude along the central Marches coast) and during the blooming 3rd and 4th centuries CE, there is also the suggestion that the eastern blocks of the city would stem from a later construction phase than the remainder of the city.

The city has always had to adapt to its physical foundation, the beach barrier, and the particular morphology of this geomorphological feature, notably the steep seaward slope of about 90 m/km or 5 and the gentle landward slope of about 30 m/km or 2 and the maximal width of about 250 m (figure 6). The landward side of the beach ridge nowadays is topped by a thick cover of clayey-loamy flood sediments, predominantly deposited during the 14th and 15th centuries. The fact that the geophysical signals of the town's structures are muffled westwards, evidences that Potentia itself was following the geometry of the beach barrier, being built on a loam layer of constant thickness on the stable gravel and sand foundation. The fact that the loam itself is sterile in terms of archaeological artefacts presence, leads to assume that the city was built in pre-existing loam or the loam was introduced as filling, foundation material (Budini & Rossini, 2001).

Towards the east, the rapid descent of the seaward slope sets in at the imaginary NNW-SSE line through augering 2. Hand augering 3 already is situated at the same level as what would be the "harbour floor". This implicates that the foundations of the eastern part of town are much less stable than the other parts. The sedimentary composition of the beach barrier cover at augering 3 can give some indications. The clayey sediments could be flood sediments, but the clay with high sand and gravel content on top represents either a very energetic environment, or a mixture of sediments, suggesting that these sediments could well be put in place there to provide in the expansion of the town.

The pottery business

As mentioned, at least two ceramics production sites have been discovered and identified as such in the coastal plain: site 127 with cooked clay and metal scorie and a remarkable high density of amphorae fragments and vernice nera, and site 111, Casa Valentini, where the wall of a ceramics furnace was preserved.
This kind of production site needs an ample supply of raw material. Studies of ceramics of Antiquity in Italy (Eramo et al., 2004) point out clayey silts, especially of alluvial origin, as ideal constituent. These sediments are omnipresent in the coastal plain of the Potenza river.
However, if the location is ideal for procuring the needed supplies, it is not so for providing a stable and dry foundation. Consequently, the production sites had to be built on stable islands in what can be described as a sea of alluvial material. In this case, site 127, just south of the eastern end of palaeochannel I, enjoys the protective shadow of it, plus it's located on some gravel spread out from this palaeochannel; while the Casa Valentini site is located on the stable abrasion platform at the base of the cliffs. To the southwest, lagoon to marshy conditions occurred, providing clay and loam of excellent quality for ceramics production and water availability, which makes its hypothesised productive function highly likely.
Site 128 is in a similar position, but on the northern side of the palaeochannel deposits, also enjoying the stable ground provided by the palaeochannel gravel, and open to the debouchment zone.

SUMMARY

With often a lack of hard evidence, the story of the coastal plain had to be built up through the search of converging elements of evidence, be it from literature review, interpretation of aerial photographs, archaeological survey, geomorphological survey, hand augerings, geo-electrical profiling, topographic survey, radiocarbon and OSL dating, mollusc analysis or other. Though already many deductions could be drawn concerning the nature of the environmental change in the coastal plain, this study will never be complete.
However, some inferences at least can be made. Four phases of coastal devel-

opment can distinguished from the late glacial period onwards. The bay was scoured and fille with loess during the pre-marine phase (phase 1) of the late glacial, and invaded again by the sea during the Versilian transgression, in the first half of the Holocene. Somewhere after 5040 ± 35 calBCE, a beach barrier system (phase 2) was built up, behind which marine and fluvial sediments could be deposited. Potentia was built on one of these beach barriers. At the base of the interfluvial hills, the abrasion platforms were terraced, due to a slowing in the sea level rise; later on, the resulting relative sea level drop also liberated some grounds upon which an eastern extension of the city of Potentia could be built. The coastal plain sediments were gradually incised by channels (phase 3), amongst others the "Roman" Potenza river, probably somewhere after 3600 ± 400 years BCE. During the late to post-medieval periods (phase 4), roughly from 1300 CE to 1700 CE, strong aggradation by fine alluvial sediments took place in the coastal plain, slowly filling the numerous local depressions in the then marshy landscape.

Meanwhile, the Potenza river deplaced its course, through avulsion, from the middle of the coastal plain (palaeochannel I) to the north. Firstly to palaeochannel II, where is was situated during the Roman age, into a debouchment zone which might have served as the harbour zone for Potentia, and which was later filled up by a deltaic system of channels which gradually shifted towards the north, eventually even erasing evidence in the southeast corner of former Potentia. This zone of continuous evolution was probably depassed by the Roman coastal road, the only exception in an otherwise strictly perpendicular road system. On the more stable positions, production sites were built: on the end of palaochannel II and on the marine terraces.To the south of palaeochannel I, a separate fluvial system dewatering towards the present Fosso Pilocco probably evolved. Finally, the last 2 km of the Potenza river were manually dug in the extreme north of the coastal plain, probably for land reclamation.

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