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Les ports dans l'espace méditerranéen antique

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sous la direction de Corinne Sanchez et Marie-Pierre Jézégou

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Connecting *Portus* with Ostia : preliminary results of a geoarchaeological study of the navigable canal on the Isola Sacra

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Résumé

Le canal romain, découvert sur l'Isola Sacra en 2011 par prospections géomagnétiques à l'embouchure du Tibre, constitue un élément clé pour la compréhension du système portuaire *Portus*-Ostie situé sur la façade maritime de Rome (delta du Tibre, Italie). Cet article propose les premiers résultats d'une étude du comblement de ce canal pour tenter de reconstituer sa morphologie initiale, les transformations qu'il a subi et son abandon. Pour y parvenir, deux transects ont été réalisés dans le secteur où le canal apparait le plus large : trois carottages ont été réalisés en travers du canal pour analyser précisément les dépôts ; un transect de résistivité électrique a été effectué pour permettre de corréler les carottes entre elles.

L'étude combinée des prospections géophysiques et des carottes permet d'envisager l'existence de quatre phases d'activités du canal. Une première phase est illustrée par un canal rectiligne entre la *Fossa Traiana* (Fiumicino) et l'embouchure naturelle du Tibre près d'Ostie (Fiumara Grande). Une deuxième phase est marquée par une mobilité latérale de la partie nord du canal ; le chenal emprunte alors un nouveau tracé (carotte CPO-2) et l'ancien se comble de sable (carotte CPO-3). Ce nouveau chenal est ensuite déconnecté à l'amont (bouchon alluvial ?), et est comblé par des sédiments fins (carotte CPO-2). Enfin, une quatrième phase d'occupation du canal apparait avec un recreusement plus tardif, très probablement pour des besoins agricoles. Avec une profondeur de 3 à 4 m sous le niveau marin romain, les deux premiers canaux permettaient la navigation de la plupart des navires antiques mais pas des plus gros vaisseaux. Une datation absolue des phases d'activité et de plus amples précisions sur les fonctions de ce canal seront apportées avec des données en cours d'analyse.

Abstract

The Roman canal, which was found using magnetometer survey in Isola Sacra (Tiber delta, Italy) in 2009 is fundamental to our understanding of the relationship between *Portus* and Ostia, which constitute the core of what has been defined as the « port system » of Imperial Rome. This article presents the preliminary results of a stratigraphical study of the canal in an attempt to reconstruct its morphology, phases of activity and eventual disuse. In order to achieve this, three cores were drilled at the widest point of the canal in order to analyse the deposits, while an Electrical Resistance Tomography (ERT) profile was undertaken to correlate the core sequences. The study of the results of this fieldwork suggests four periods of use. A first phase comprises a straight canal running between the *Fossa Traiana* (Fiumicino) and the natural mouth of the Tiber near Ostia (Fiumara Grande). A second phase is marked by a lateral mobility of the northern part of the canal, this means that the canal took a new route (CPO-2 core) while the earlier course had been sedimented (core CPO-3). This new stretch of the canal was probably disconnected upstream from the Fiumicino and filled-in with fine sediment (core CPO-2). Finally, a fourth phase of use appears with a later recut of the second phase of the canal, most likely for agricultural purposes. With a depth of between 3 and 4 meters below the Roman sea level respectively, the first two canals would have been navigable by many kinds of ancient boats but not larger vessels. These phases of canal activity are in the process of being given absolute dates.

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Mots-clés
Portus, Ostie, canal romain, géoarchéologie, prospections géophysiques, Isola Sacra, delta du Tibre, Italie.

Keywords
Portus, Ostia, Roman canal, geoarchaeology, geophysical survey, Isola Sacra, Tiber delta, Italy.

1. Introduction

The geoarchaeological study of Roman navigation canals is an active area of research (Salomon *et al*. 2014c). Recent publications have focused on those in deltaic areas across the Mediterranean sea (Rhone delta : Vella *et al*. 1999 ; Aude delta : Ambert 2000, 2011 ; Po delta : Rousse 2005 ; Nile delta : Wilson 2012) and in temperate Europe (Rhine delta : Kort, Raczynski-Henk 2014). In this promising area of research, canals excavated before and after the Roman period have also been studied from a geoarchaeological perspective (the canal of Xerxes in Greece : Isserlin *et al*. 1994, 2008 ; the canal of Charlemagne in Germany : Zielhofer *et al*. 2014). The geoarchaeological investigation of the canals at *Portus* began after the completion of the large-scale magnetometry survey undertaken between *Portus* and Ostia (Keay *et al*. 2005)[1], and has involved the sampling of geophysical anomalies by a mechanical corer (Salomon *et al*. 2012, 2014a ; Salomon 2013) (fig. 1). The discovery of the *Portus* to Ostia canal was one of major discoveries of the magnetometry survey undertaken on the Isola Sacra (Germoni *et al*. 2011).

Learning of this canal's existence is a key piece of evidence when considering that Ostia and *Portus* formed part of a unified harbour system. The former was the Republican harbour of Rome at the mouth of the river Tiber (Calza *et al*. 1953 ; Zevi 2001, 2002), to which the harbour of *Portus* was added in c. AD 42-46 (Keay *et al*. 2005 ; Keay, Paroli 2011). The reason for the construction of *Portus* and its associated canals was probably due to several reasons, including the need to ensure a steady supply of imported foodstuffs to the capital, to relieve the danger of Tiber floods and to avoid the environmental pressures prevailing on the fluvial harbour of Ostia (Meiggs 1960 ; Keay *et al*. 2005, 297-305 ; Salomon 2013 ; Goiran *et al*. 2014). The harbour was transformed at the beginning of the 2nd century AD during the reign of the Emperor Trajan, with the addition of an internal hexagonal harbour basin.

Following its establishment, *Portus* was intimately connected to Ostia in administrative terms (Meiggs 1960 ; Gallina Zevi, Claridge dir. 1996) and in the physical sense, and only gained municipal status in the early 4th century AD. Until recently, apart from the river Tiber, the *Via Flavia* which crosses the Isola Sacra from *Portus* to Ostia, together with its associated cemetery, were the only manifestations of the physical link between both ports (Germoni *et al*. 2011). However, the recent discovery during a magnetometer survey of a major new canal running southwards from *Portus* is additional evidence for the importance of this relationship (Germoni *et al*. 2011 ; Keay *et al*. 2014a), and the broader inter-connectivity of the canal system at *Portus* (Testaguzza 1970 ; Keay *et al*. 2005 ; Salomon 2013).

This paper approaches the study of this new canal from an interdisciplinary perspective. The canal was sampled by means of an Electrical Resistivity Tomography (ERT) traverse and a sequence of three boreholes that ran across the width of the canal from west to east, so that they complemented the published magnetometer survey results (Germoni *et al*. 2011 ; Keay *et al*. 2014a). This complementary analysis has made it possible to provide a third dimension to our understanding of the canal, namely its depth and stratigraphic sequence. The location of the ERT and coring transects was chosen at the point where the canal was at its widest, extending for c. 90 m from west to east. This paper attempts to provide initial answers to key questions about the canal. Why was it so wide ? What was its profile ? What was its depth ? What were its dynamics ? It is hoped that our results will help us to better understand the hydro-sedimentary characteristics of the canal, its uses and its functions.

2. Geographical and archaeological context

2.1. Palaeogeomorphology of the Isola Sacra – Tiber delta

The Isola Sacra is an artificial island located between the sea and the two branches of the river Tiber : the natural channel of the Fiumara to the east and south, and the Fiumicino, which was initially a Roman canal, between the Tiber and the sea to the north (fig. 1). This area corresponds to the outer plain of the Tiber delta. It is a strandplain that has extended westwards towards the sea since c. 6500 BP (Bellotti *et al*. 2007 ; Milli *et al*. 2013) and

1. *PortusProject* : http://www.portusproject.org/ ; now part of the *PortusLimen Project,* an ERC funded program : http://portuslimen.eu/

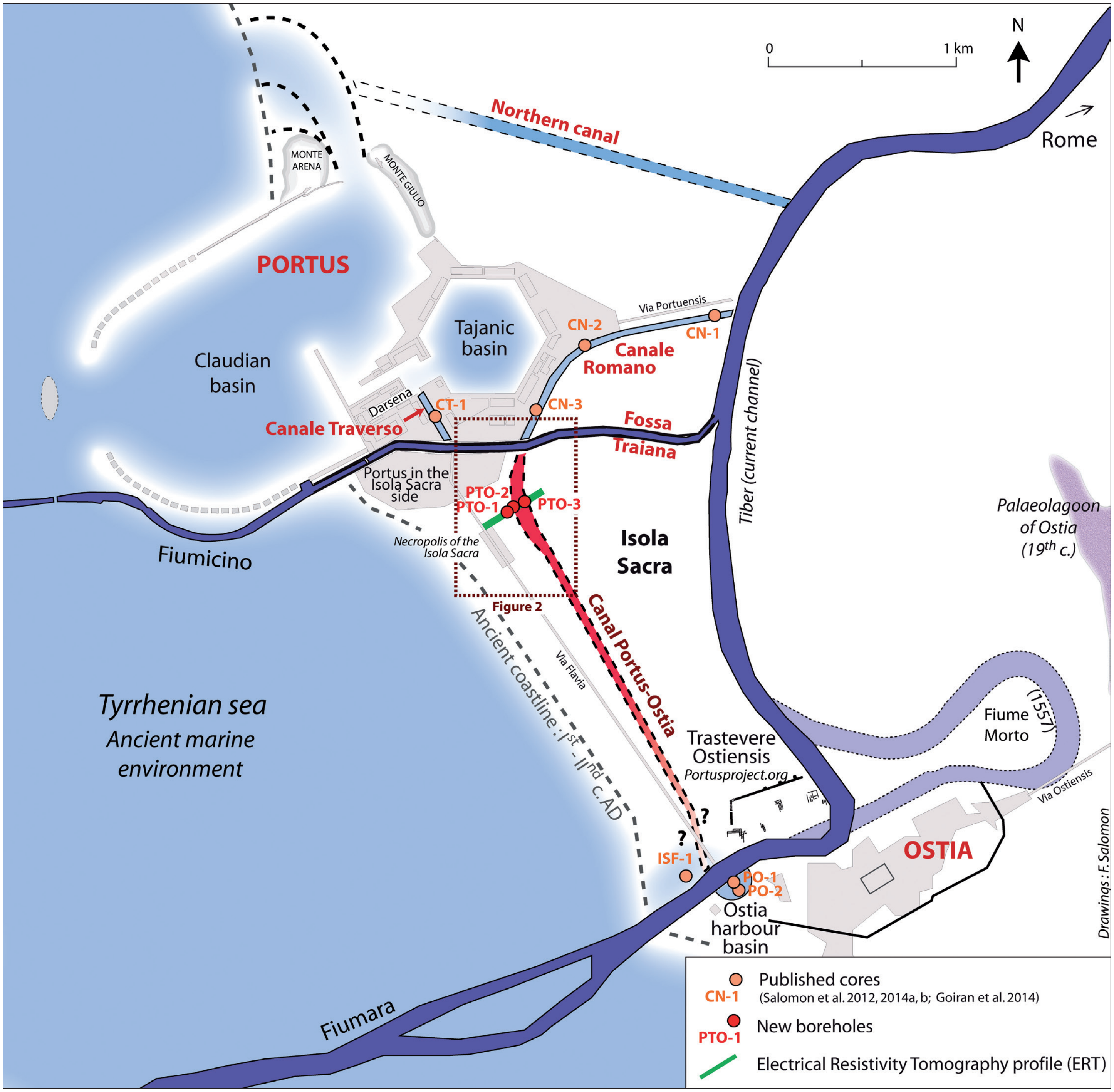

Fig. 1 : Location map. The *Portus*-Ostia harbour system and the location of the *Portus*-Ostia canal.

which is related to specific periods of faster coastline mobility westwards (Giraudi 2004), notably during the Roman period (Bicket *et al.* 2009). Strandlines are visible in the results of magnetometer survey of the northern part of the Isola Sacra (Keay *et al.* 2014a ; 2014b) and can be correlated with those observed using the same method to the north of the Fiumicino (Keay *et al.* 2005).

Mobility of the Tiber during the Holocene is more difficult to recognise. The Tiber channel has been identified through the use of boreholes (Bellotti *et al.* 2007 ; Salomon 2013), aerial photographs (Shepherd 2006) and magnetometer survey (Keay *et al.* 2005). The most recent magnetometer survey revealed evidence that suggests that the southern part of the Isola Sacra formed part of the lateral movement of the Holocene Tiber channel (Keay *et al*. 2014b) ; this was confirmed by the results of the analysis of bore-hole cores (Salomon *et al*. 2014b). Some evidence for the location of the Roman coastline on the Isola Sacra has been provided by Arnoldus-Huyzendveld (2005) and Germoni *et al*. (2011).

2.2. Geoarchaeology of the harbours of Ostia and *Portus*

Our understanding of the harbour system of *Portus* and Ostia has been considerably enhanced over the last decade through geophysical survey, together with geoarchaeological research. The analysis of core sequences from the latter has been especially useful at *Portus*, providing new clues about the location of a major entrance to Claudian harbour to the west (Goiran *et al*. 2011 ; Morelli *et al*. 2011) and a secondary entrance to the north (Goiran *et al*. 2011), as well as helping us better understand the bathymetry and the currents within the Claudian basin (Goiran *et al*. 2010 ; Millet *et al*. 2014). Palaeoenvironmental analyses have also provided us with data for reconstructing vegetation and neighbouring water sources (Goiran *et al*. 2010 ; Sadori *et al*. 2010 ; Mazzini *et al*. 2011 ; Pepe *et al*. 2013 ; Delile *et al*. 2014). At Ostia, a geoarchaeological survey confirmed the location of the harbour basin close to the mouth of the Tiber and suggested that it was in use between the 4th-3rd century BC and the 1st century AD (Goiran *et al*. 2014).

2.3. Geoarchaeology of the canals of *Portus*

The canals of *Portus* have been the subject of discussion since the 19th century. Carlo Fea, for example, wrote a small monograph on the *Fossa Traiana* and identified it with the Fiumicino on the basis of studying ancient texts (Fea 1824). Its brick-lined edges were discovered during reclamation work at the beginning of the 20th century. and again in the 1970's (Testaguzza 1970 ; Veloccia Rinaldi 1975). It has been dredged several times since the Roman period as well, a process which has involved the removal of much of its sedimentary archive. No boreholes have, as yet, been drilled into it. .

The geoarchaeological study of the *Portus* canals started with the *Canale Traverso*. It is the only canal that connected the fluvial system to the harbour basins. It is very narrow, connected secondarily to the Tiber river channel, and has a sedimentary facies that is more akin to that of a harbour environment; indeed, it has yielded few coarse sediments (Salomon *et al*. 2012). This canal has been studied from a geoarchaeological (Salomon *et al*. 2012) and palaeoenvironmental perspective (Sadori *et al*. 2010 ; Mazzini *et al*. 2011 ; Pepe *et al*. 2013). Its location within the harbour system has allowed researchers to determine the fluvial inputs inside the harbour basins (including silt and clay sediments, coarse sediments, and *alnus* pollen). This issue was also studied by means of geochemical indicators (Delile *et al*. 2014). It appears that both fine and coarse sediments were deposited in the canal by fluvial action in the course of being transported into the Trajanic basin.

The second canal to have been studied from a geoarchaeological perspective was the *Canale Romano*, an archetypal fluvial canal. Its existence was conjectured by Testaguzza (1970), presumably on the basis of aerial photography, but it was not actually found until the magnetometer survey of the harbour and its environs in 1999 (Keay *et al*. 2005). Three borehole surveys have been conducted in this canal subsequently (Salomon *et al*. 2014a). They revealed a stratigraphic sequence composed of coarse fluvial sediment (bedload) at the bottom of the sequence, which was then covered by silty-clay deposits above. The sharp transition between these two facies is probably due to an upstream cut-off of the canal, similar to a palaeomeander cut-off (Knighton 1998 ; Bravard, Petit 2000). This simple stratigraphic interpretation is made more complex by the presence of very fine deposits trapped inside the coarse deposits at the bottom of the canal sequence. Two hypotheses have been proposed to explain this : (1) an upstream control in the form of a system of locks ; or most probably (2) a downstream control caused by the mobility of the salt edge (meeting area of the fresh and salt watertables) into the fluvial channels, thereby leading to the accentuation of flocculation (Salomon *et al*. 2014a).

The Fiumicino (*Fossa Traiana*), *Canale Traverso* and *Canale Romano* canals are interconnected and linked to the Tiber river channel at the upstream end of the *Canale Romano* and Fiumicino canal. A fourth canal was identified to the north, visible in air photographs taken by the RAF in 1943 (Testaguzza 1970 ; Keay *et al*. 2014a), and in the magnetometer surveys from 2004 and 2005 (Keay *et al*. 2005), but this canal runs on a different path, connecting the Tiber with the northern entrance of the Claudian harbour basin and the sea beyond. The fifth canal, which runs between Ostia and *Portus*, was connected to the Fiumicino canal and can therefore be considered to have formed part of a complex network of canals that included the *Canale Romano* and the *Canale Traverso*.

2.4. Archaeology of the *Isola Sacra*

The name of the *Isola Sacra* (« Sacred Island ») was first coined in the 6th century AD (Procopius, 5, 26, 3-19). The landmass may have been used for agricultural purposes (Keay *et al*. 2014a), but salt production is also a possibility. On the northern side of the Isola Sacra, a community linked to *Portus* appears in the 2nd century AD (Veloccia Rinaldi

1975). To the south, recent magnetometer surveys have demonstrated the continuation of the urban fabric of Ostia on the northern side of the Tiber at the southern end of the Isola Sacra (Keay *et al*. 2014b ; http://www.portusproject.org/blog/2014/04/new-city-wall-discovered-ostia/), making it clear that the Tiber channel did not act as the definitive northern limit of the city of Ostia. There is no firm evidence as yet for the existence of a bridge across the Fiumara Grande during the Roman period, suggesting that ferryboats may have transported traffic across the river. On the other hand, there is evidence for the existence of a bridge spanning the Fiumicino canal between the northern edge of the Isola Sacra and the south side of *Portus*, the so-called *Ponte di Matidia* (Geremia Nucci 2000). An inscription found close to the site of this bridge records two phases of restoration, one dating to the first quarter of the 5th century AD and the other to the Ostrogothic period (Keay *et al*. 2005, 317, no.11). The Isola Sacra was above all, therefore, an area of passage between *Portus* and Ostia. It was crossed by the *Via Flavia*, which was established in the late 1st century AD, and along which there developed a cemetery, which was in use primarily between the late 1st and 4th century AD (Baldassare *et al*. 1996 ; Baldassare 2001).

3. METHODS

3.1. Magnetometry survey

The success of the fluxgate gradiometer surveys in facilitating the mapping of sub-surface archaeological structures across the landscape and hinterland of *Portus* since the late 1990's (Keay *et al*. 2005 ; Strutt, Keay 2008) made this the logical choice for undertaking a relatively rapid survey of the Isola Sacra (fig. 2) ; it also ensured that the results from both areas were comparable as well. The technique works by measuring minor changes in the earth's magnetic field, allowing the detection of many different types of archaeological features including kilns, hearths, ovens, ditches and walls, particularly where ceramic material or tufa have been used in construction. The variation of sands and sediments associated with channels, ditches and other waterways across the survey area meant that this technique provided the best method for mapping these features. The magnetometer survey was undertaken using a Bartington Instruments Grad601-2 Dual Array Twin Fluxgate Gradiometer (Germoni *et al*. 2011). Readings were taken at 0,25 m intervals along traverses spaced every 0,5 m, within 30 by 30 m grids, giving a high-resolution for detecting archaeological remains. The data were recorded using a Grad-01 Data Logger. The data were processed in Geoplot 3.0 software to remove any environmental disturbances or variations produced in the course of the survey. Firstly data were manipulated to remove any distorting « spikes » from the survey results. A zero mean traverse function was then applied to remove the effect of drift caused by changes in the Earth's magnetic field. A destagger function was used to minimise any potential staggering in the results caused by the zig-zag pattern of walking. A low pass filter was then also used to filter out any modern high frequency anomalies (Keay *et al*. 2014b). This survey located clear traces of the channel in the northernmost part of the Isola Sacra. It opens off the southern side of the Fiumicino canal, c. 300 m east of the early Medieval church of Sant'Ippolito, almost opposite the mouth of the *Canale Trasverso* on the northern bank of the Fiumicino canal (fig. 2). It measures c. 90 m wide, and can be traced running southwards for well over 600 m, separating the cemetery that runs either side of the Via Flavia from the *statio marmorum* to the north-east. While its eastern side is quite well defined, inviting similarities to the *Canale Romano* further to the north, its western

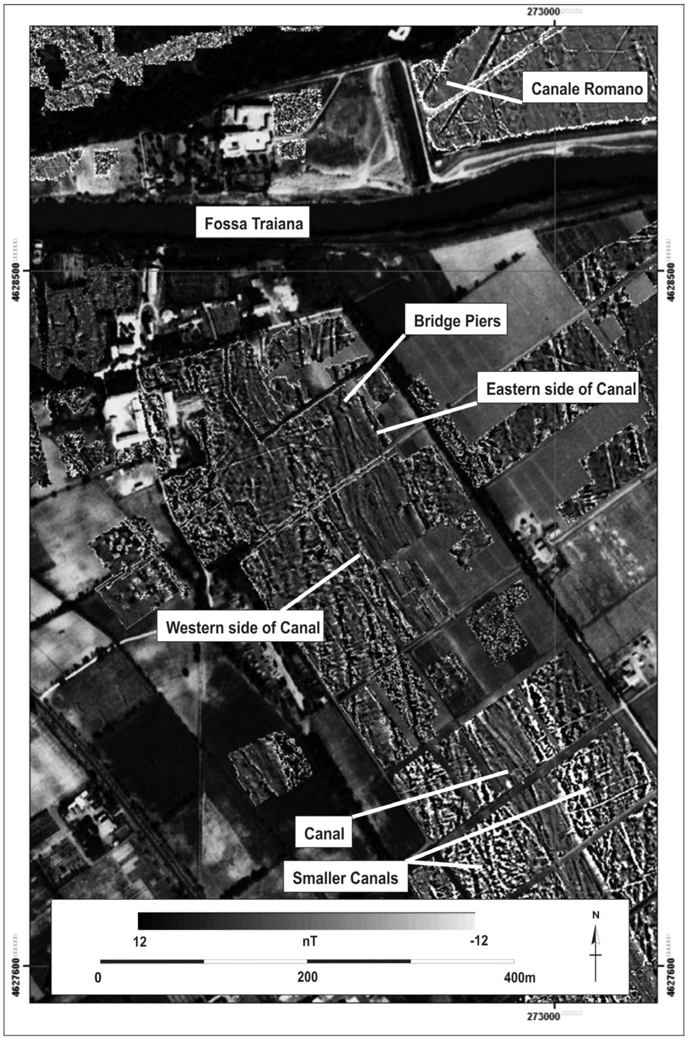

Fig. 2 : Detail of the results of the magnetometer survey of the Isola Sacra overlaid onto an aerial photograph dating to 1957 (Keay *et al.* 2014a) : it shows the canal and associated features.

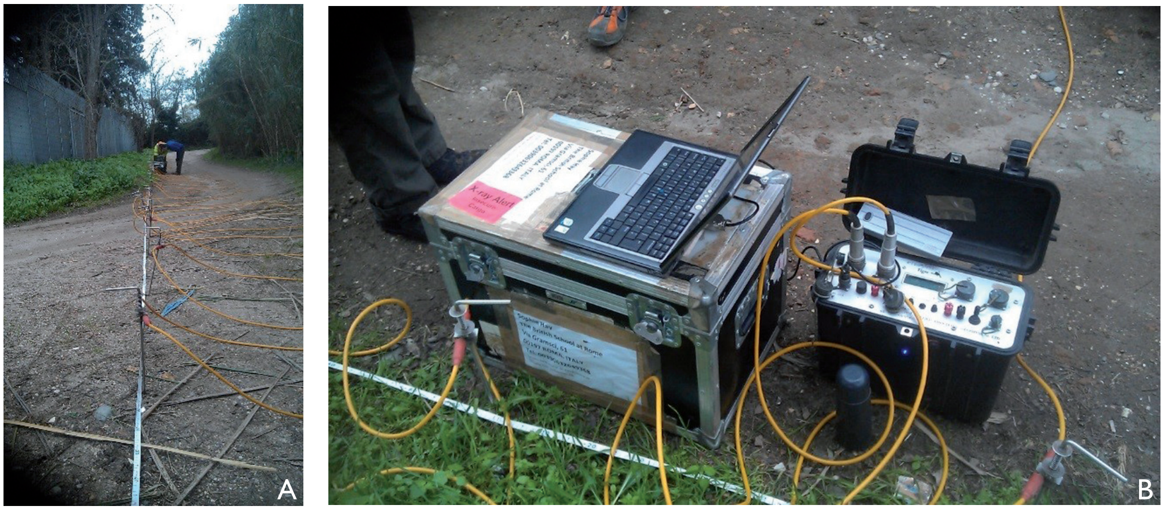

Fig. 3 : (A) Setting out of the ERT probes and checking on the Tigre ; (B) The Allied Associates Tigre Resistivity meter during the ERT survey (K. Strutt).

edge was less clear. The current interpretation suggests that there was what appears to have been an island in the centre of the canal, while further to the north the canal was straddled by a bridge, two of whose brick-faced piers still survive (Germoni *et al*. 2011, 238-239 and fig. 12.4, 12.5).

3.2. Electrical Resistivity Tomography survey (ERT)

As part of the ongoing survey of the Isola Sacra by the *Portus Project*, an Electrical Resistivity Tomography (ERT) profile was surveyed across a stretch of the northern part of the study area in November 2013 (fig. 3 and 5). The aim was to characterise and assess the depth and profile of the Isola Sacra canal located by means of the magnetometer survey. This technique relies upon passing an electrical current through the earth, and measuring the resistance to the current at intervals to build up a profile of the changing material below the surface of the ground, thereby enabling features and anomalies to be located and mapped. For the survey, a Tigre 64-probe system was used. Measurements were taken using an expanding Wenner array (fig. 3), with readings taken with the probes at differing intervals for each profile, according to the length and depth required to learn more about the depth and profile of the canal. A reading was taken at the centre of four probes chosen by the computer programme starting with probes 1, 2, 3 and 4, the reading was taken at the centre of the probes. The depth at which measurements were taken corresponded to approximately half the distance between the individual probes; in other words the probes were set at 1m spacing so that readings could be taken every 1 m horizontally and every 0,5 m vertically below the ground – at increasing depth down to 7 m. The data was processed and inverted using the Res2DInv software program. Topographic data was taken from the LiDAR data for the area to give the variations in the topography along the length of the profile.

3.3. Bore-holes and palaeoenvironmental analysis

Three cores were drilled across the widest part of the canal with a rotary corer in November 2013. One core was located on the western side of the canal, in what it is considered to have been the strandplain (OST-1). Since the canal seemed to be bifurcated into two channels, a separate core was also drilled in each of these (OST-2 and 3) (fig. 4 and 6). Several analyses of the drilled cores from these boreholes are currently in process, so that the date of the canal (excavation, periods of use and abandonment), its hydrodynamism, and the conditions of the deposits within the canal could be gauged. The analysis includes radiocarbon dating, magnetic susceptibility, Itrax scanning, laser grain-size analysis, as well as wet sieving, the first results of which are provided in this paper (Coarse deposits : > 2 mm ; Sands : 2 mm to 64 m ; Silts and clays : < 64 m) (fig. 6).

Fig. 4 : Mechanical corer (Core CPO-3) in the field on the Isola Sacra (F. Salomon).

4. THE CANAL BETWEEN *PORTUS* AND OSTIA – PRELIMINARY RESULTS

Figure 5 presents the preliminary results of the three complementary approaches used in the study of the *Portus* to Ostia canal : magnetometer survey, followed by *Electrical Resistivity Tomography* (ERT), and finally sedimentary cores (fig. 6). The first of these techniques provides a detailed map of the subsurface at a depth of c. 1,5 m, in which the resolution of anomalies that can be associated with archaeological features stand-out very clearly. The ERT results complement this by giving us an impression of the diversity of different kinds of subsurface anomalies at greater depths. Borehole cores, by contrast, provide direct samples of the subsurface features detected by the other methods. Magnetometer images take the form of extended integrated maps (x-axis, and y-axis), while ERT deals with continuous stratigraphy (z-axis with x- or y-axis). Consequently, while the order of the three stages of analysis in figure 5 is relevant in a protocol for how one approaches the characterization of a palaeo-canal, their interpretation has to be undertaken by continuously cross-referring between all three datasets.

4.1. Upstream and downstream junctions of the canal – Magnetometer survey interpretation.

While the magnetic survey makes it possible to identify the path taken by the canal between *Portus* and Ostia, there is need of further research into its connections in the north, and particularly the south (fig. 2). Concerning the former, the canal was connected to the Fiumicino canal (*Fossa Traiana*) although the presence of ancient and modern embankments hinder surveys along much of its length. It seems that the junction lay opposite the entrance to the *Canale Romano*, as work undertaken when the Fiumicino canal was widened in the early 20th century showed that the southern side of the ancient canal was heavily built up to the west of this (Germoni *et al*. 2011, gazetteer no. 5 ; Notizie degli Scavi 1911, 410-416). The nature of the southern end of the canal as it approaches Ostia is unclear at present, although it would seem likely that it flowed into the Tiber a short distance east of the river mouth. Ongoing research is aiming to resolve this problem by integrating magnetometry, aerial photography, sedimentary core data.

4.2. The shape of the canal – Electrical Resistivity Tomography (ERT) and magnetometry survey interpretation

The magnetometer results suggest that the canal was c. 90 m wide at its northern end and c. 25 m in the south (fig. 2), with the former being the focus of this paper (fig. 5). It would also appear that it had uneven edges with no evidence for a built revetment on both sides, and that its infill was not uniform and was comprised of different phases of sedimentation. All of this information supports the hypothesis of a lateral mobility of the northern canal and several phases of reuse. The study area seems to have been characterized by the presence of an alluvial island in the middle of the canal. The presence of a brick-faced concrete pier in a field just to the north of this, together with the presence of a line of pronounced magnetic anomalies have been interpreted as piers of a bridge (Germoni *et al*. 2011 ; Keay *et al*. 2014b) (fig. 2). A shallow band of low resistivity responses between 80 m and 96 m of the transect probably marks a later recut of the canal (fig. 5).

The difference in the depth of the two sides of the canal, -3,50 m RSL. (Roman Sea Level according to Goiran *et al*. 2009) on the western side and -2 m RSL to the east (fig. 6), together with the later recut of at least 2 m depth, suggests that there were a number of different phases of cutting and recutting of stretches of the canal. The difference in the depth of high resistance anomalies of between 150 m and 200 m to the east, as well as those to the west, is also interesting, and may have been caused by varying depths of deposit across the delta. The eastern part of the profile also shows 1-2 m of alluvial sediment deposited by periods of flooding, a deposit that is not present further to the west.

4.3. Lateral mobility of the canal, and its recut – Core analysis, Electrical Resistivity Tomography (ERT) and magnetometry survey interpretation

All three cores are composed at the top of the sequence by brown silty-clay deposits that most probably derive from floods or the agricultural enrichment of soil (fig. 6). Very well-sorted sandy sediment has been observed in the sequence of CPO-1 from the bottom to the upper lying brown silty-clay unit. Similar materials are found at the bottom of the cores CPO-2 and CPO-3 (units A in CPO-2 and CPO-3). These deposits are similar to the beach-ridge deposits found in the outer delta plain (Millet *et al*. 2013). Units B, C and D of CPO-2 and unit B of CPO-3 are mostly composed of fine gravel and very coarse sand with ceramics. These sediments resemble the bedload deposits identified in the *Canale Romano* (Salomon *et al*. 2014a). The medium sand overlaps the bedload deposits in CPO-3. This palaeo-canal 1 was filled by sandy deposits (CPO-3). On the contrary the palaeo-canal 2 was filled by silty sand deposits.

There are two hypotheses that could explain the movement of the palaeo-canal 1 (CPO-3) to the palaeo-canal 2 (CPO-2). Either we have an avulsion, with the quick substitution of the palaeo-canal 1 by the palaeo-canal 2, or we have a migration of the palaeo-canal 1 to the

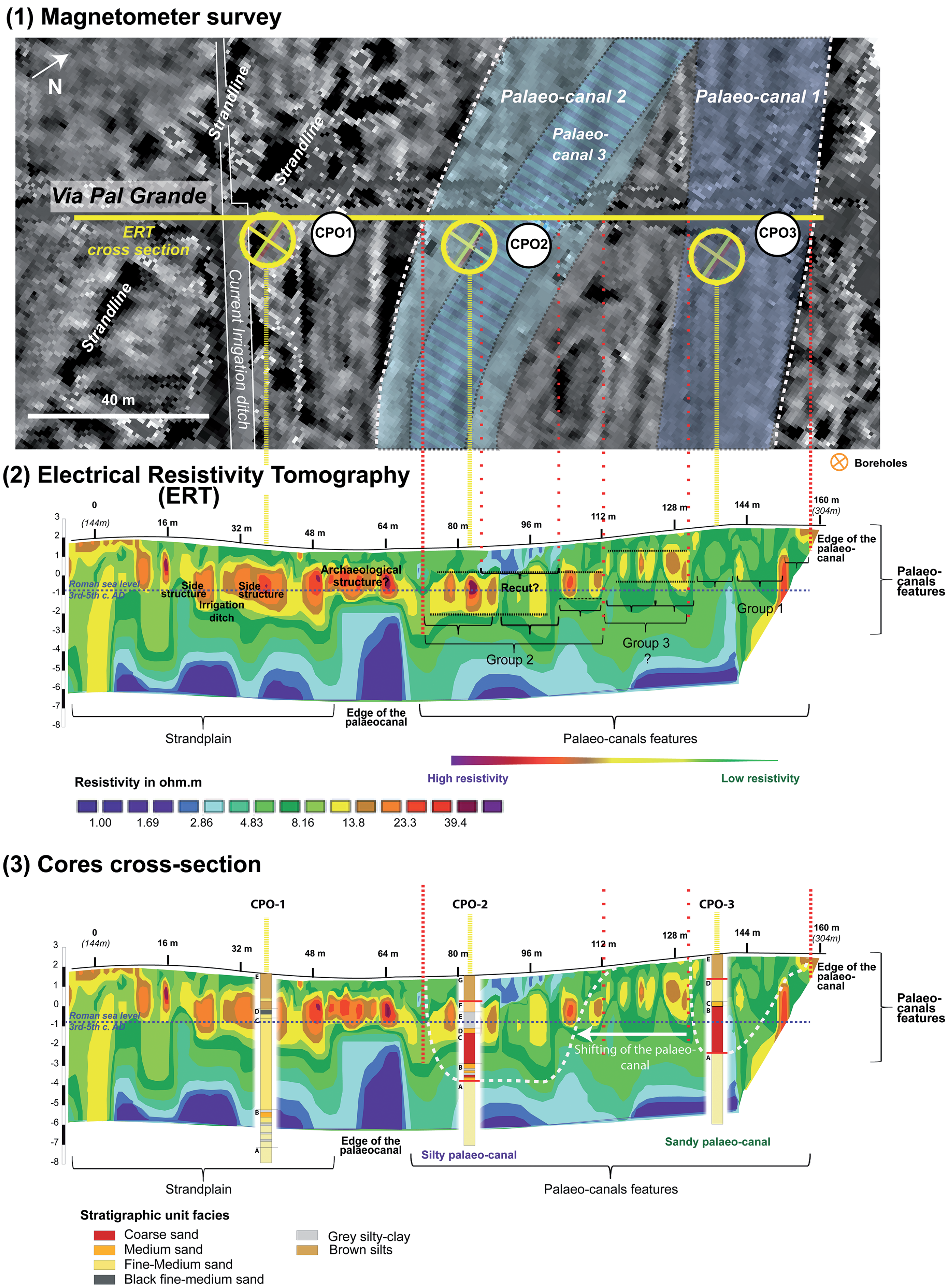

Fig. 5 : Detailed study of the northern part of the *Portus*-Ostia canal.
Magnetometer survey, Electrical Resistivity Tomography (ERT) and borehole cores.

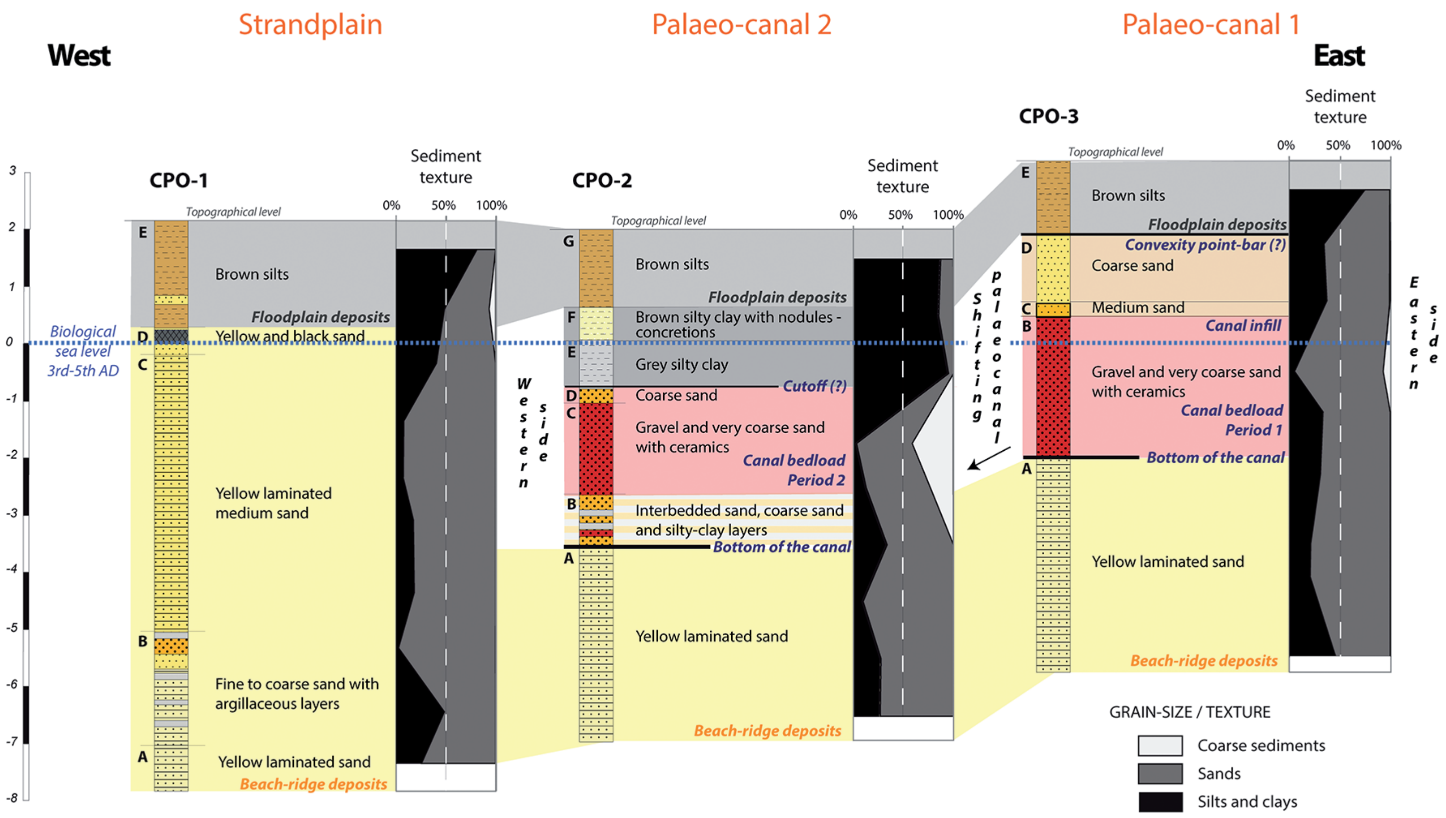

Fig. 6 : Cross section of cores taken across the Canal *Portus*-Ostia, showing grain-size texture.

palaeo-canal 2. Both hypotheses are compatible with the sandy filling of the first palaeo-canal : (1) by a construction of a point bar in the case of a channel migration ; (2) by a rapid infill of the first channel in case of an avulsion. Finally, there was a later man made recut of the second palaeo-canal by a small channel that can be observed in the results of the magnetometer and the ERT results. This palaeo-canal is connected to a smaller irrigation/drainage network (fig. 2).

4.4. Water depth of the canals – Core analysis and Electrical Resistivity Tomography (ERT)

During the Roman period, the first palaeo-canal was around 2 m deep. The second palaeo-canal, which was shaped by natural processes but which may also have been dredged, was 3,5 m deep. This interpretation takes into account the Roman Sea Level identified at *Portus* and dated to the 3rd-4th century AD (Goiran *et al*. 2009). The third palaeo-canal (recut) can be identified from the low resistivity anomalies visible in the ERT results ; but it is unclear whether the deposits just below this are also from the palaeo-canal, and the stratigraphic context of these features is unclear. What is known of the draught of contemporary Roman ships and boats (Boetto 2010), suggests that river craft would have been able to use palaeo-canals 1 and 2.

4.5. The canal *Portus*-Ostia in its context

The *Portus* to Ostia canal essentially connects two water courses – the Fiumicino canal and the Tiber/Fiumara Grande. A good comparison for a canal running along backward the shore line and between two river mouths would be the *Fossa Corbulensis* in the Netherlands, which connects the mouths of the Rhine and the Meuse (Kort, Raczynski-Henk 2014). The *Portus*-Ostia canal also complements the terrestrial route between the ports – the *Via Flavia* –, and could have would have obviated the need for hazardous coastal journeys by small boats and barges between *Portus* and Ostia. It would have also created a more efficient navigable link between the both ports by cutting out the eastern meander of Ostia. Finally, the canal would have relieved the likely traffic congestion that flowed along the Tiber through Ostia, since *horreae* are now known to have occupied both sides of the river (Bukowiecki, Rousse 2007 ; Bukowiecki *et al*. 2008 ; Keay *et al*. 2014b).

5. CONCLUSION

In the archaeological literature, the Fiumicino canal has up until now been considered as the centre-piece of the canal system of *Portus*. It was the spine of a canal network connecting the Tiber to the sea and allowing connections between the *Canale Romano* and the *Canale Traverso*. The discovery of the *Portus*-Ostia canal offers us a more nuanced view since it clearly became the central spine of a harbour system that integrated connectivity between *Portus* and Ostia.

Initial research suggests that this canal was used for waterborne communication between *Portus* and Ostia. The core sequence presented in this paper suggest that it had an average depth of between 2-3,5 m, sufficient to accommodate many of the known ship types that plied the waters of *Portus* (Boetto 2010), although smaller vessels are more likely than the larger ships. The magnetometry survey did not provide any evidence for revetted sides to the canal, a characteristic that goes some way to explaining the lateral mobility of the canal. Our results suggest that it may have functioned like a natural river channel, with lateral adjustments to hydro-sedimentary flows and episodes. Indeed, both the ERT survey and borehole cores point to the erosion of the eastern side of the canal (CPO-2), and the infilling of the first palaeo-canal (CPO-3). The second canal was subsequently disconnected from the flows coming from further north and infilled by silty-clay deposits overlying the coarse bedload deposits (CPO-2). Finally, a third canal was discovered with a combination of ERT and magnetometer survey; this was subsequently recut for agricultural purposes.

All of this evidence suggests that the *Portus* to Ostia canal was shaped by morphogenic floods and that it also formed part of the system of flood-relief canals of *Portus* (Testaguzza 1970 ; Keay, Paroli 2011 ; Salomon 2013). More precise analysis is in progress on the sediment content of the canal, in the hope that it will provide us with more reliable evidence on these matters, while ^{14}C dating will provide us with an absolute chronological framework within which to better understand this canal and its context.

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