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The *Canale di Comunicazione Traverso* in Portus: the Roman sea harbour under river influence (Tiber delta, Italy)

Etude du Canale di Comunicazione Traverso *à Portus : le port maritime antique de Rome sous influence fluviale (delta du Tibre, Italie)*

Ferréol Salomon*, Hugo Delile*, Jean-Philippe Goiran**, Jean-Paul Bravard*, Simon Keay***

Abstract

Portus was Rome's maritime port during the Roman Empire. In AD 42, the harbour location was selected about 3 km north of Ostia, along the Tyrrhenian coast, on the margin of the Tiber River. *Portus* and its maritime façade are well known, however the fluvial aspects of *Portus* are poorly documented. How did Roman engineers preserve a continuous waterway from the basins of *Portus* to the Tiber River without accelerating siltation inside the harbour? Were their choices efficient? The present *Canale di Comunicazione Traverso* is the only canal attested to link the Tiber River and the harbour basins. The objective of this work is to analyse the *Canale Traverso* sediments infill in order to establish the role of this canal in relation to the infill deposits of the harbour basins and to define the functions of the canal. This study is based primarily on a reinterpretation of the available archaeological data, as well as mainly on sedimentological analysis and the interpretation of the Passega diagram. A Passega diagram is presented for understanding the deposit processes for the harbour environments at the entrance to the Trajanic basin (TR-XIV). This diagram is compared to the Passega diagram of the *Canale Traverso* (CT-1) which is characterised by a stronger influence of the Tiber River. This study concludes that the *Canale Traverso* was a canal that was well protected from the influence of the Tiber River, with the exception of occasional flooding. Also, this paper presents the patterns of sedimentation at *Portus* and allows us to define the use of the canal and the maintenance procedures.

Key words: geoarchaeology, Roman harbour, Roman canals, late Holocene, Tiber delta, Rome, Italy.

Résumé

Portus *était le port maritime de Rome à l'époque impériale. En 42 apr. J.-C., le site d'implantation de ce port fut choisi à environ 3 km au nord d'Ostie, le long du littoral Tyrrhénien, mais en marge du Tibre. Si aujourd'hui on connaît bien* Portus *et sa façade maritime, on connaît moins bien* Portus *et son aspect fluvial. Selon nos connaissances actuelles, le* Canale di Comunicazione Traverso *est le seul canal attesté permettant la liaison entre le fleuve et les bassins portuaires. Comment les ingénieurs antiques ont-ils concilié l'existence d'une voie de navigation continue entre le système portuaire et le Tibre et la protection des bassins vis-à-vis des apports sédimentaires fluviaux ? Ces aménagements furent-ils efficaces ? Les objectifs de ce travail sont l'analyse précise des modalités de colmatage du* Canale Traverso *de manière à établir son rôle dans la sédimentation des bassins de* Portus *et la définition du fonctionnement et de l'usage de ce canal. Cette étude se base sur une relecture des données archéologiques et principalement sur des analyses granulométriques, et sur l'interprétation du diagramme de Passega. Une image assez complète des processus de dépôt en milieu portuaire est donnée à l'entrée du bassin de Trajan (TR-XIV). Ce diagramme de Passega est comparé à celui du* Canale Traverso *(CT-1) soumis davantage à l'influence du Tibre. Les résultats obtenus postulent en faveur d'un canal plutôt bien protégé de l'influence fluviale avec l'incursion épisodique des crues du Tibre. Cet article est également l'occasion d'étudier les rythmes de la sédimentation à* Portus *afin de définir l'usage de ce canal et les modalités de son entretien.*

Mots clés : géoarchéologie, port romain, canaux romains, Holocène récent, delta du Tibre, Rome, Italie.

Version française abrégée

Le cœur de cette étude est un transect de carottages réalisés entre le Canale di Comunicazione Traverso *et le chenal d'accès au bassin de Trajan dans le* Portus *de Rome (CT-1 et TR-XIV ; fig. 1 et fig. 2). Diverses analyses ont été réalisées sur les carottes (fig. 5 et fig. 6) : granulométrie, taux de matière organique, susceptibilité magnétique (fig. 4), densité apparente, interprétation du diagramme CM de Passega (1957 ; fig. 7). Ce travail concerne en particulier les données*

* Université Lumière (Lyon 2) - CNRS-UMR 5600 - 5, avenue Pierre Mendès-France - 69676 Bron Cedex - France (ferreol.salomon@univ-lyon2.fr; hdelile@gmail.com; jean-paul.bravard@univ-lyon2.fr).
** CNRS-UMR 5133 - Maison de l'Orient et de la Méditerranée - 7, rue Raulin - 69007 Lyon - France (jean-philippe.goiran@mom.fr).
*** University of Southampton - School of Humanities, Archaeology - Avenue Campus - Southampton, SO 17 1 BF - Great Britain (sjkl@soton.ac.uk).

granulométriques et les questions de dynamique sédimentaire en milieu fluvio-marin portuaire. Dans ce secteur de Portus*, trois publications récentes (Goiran* et al.*, 2010 ; Sadori* et al.*, 2010 ; Mazzini* et al.*, 2011) développent l'aspect plus proprement paléoenvironemental avec des analyses macro- et microfaunistiques et la détermination des pollens présents. Une synthèse de ces résultats, plus spécifiquement orientée sur l'ostracofaune (fig. 3), confirme une très nette différence entre le bassin du port de Claude, où dominent les eaux salées, et le chenal d'accès au bassin de Trajan marqué par la rencontre des eaux salées et douces. Mais avant tout, pourquoi tant d'études récentes ont-elles concerné ce petit canal ? Le* Canale Traverso *est le seul lien entre le complexe portuaire de* Portus *et le système fluvial du Tibre. L'enjeu pour les ingénieurs romains était donc de 1) réaliser une voie navigable continue entre les bassins portuaires et le Tibre tout en 2) évitant l'envasement accéléré de ces bassins par les apports fluviaux (Reddé, 1986). Le* Canale Traverso *aurait été pensé pour satisfaire ces deux objectifs (Le Gall, 1953). Le présent travail se situe ainsi à l'interface des études de géoarchéologie fluviale et portuaire.*

Le Canale Traverso *a probablement été creusé dès le I[er] s. apr. J.-C. (Keay* et al.*, 2005). Le plan dressé par les archéologues (Lugli et Filibeck, 1935 ; Keay* et al.*, 2005) révèle son implantation assez particulière (fig. 2) puisqu'il est en connexion secondaire avec le Tibre : le* Canale Traverso *(sud-nord) s'embranche en effet sur le canal de Fiumicino (est-ouest) à 1500 m du Tibre actuel. Ce tronçon amont du Fiumicino correspond à la probable* Fossa Traiana *antique qui se jetait dans la mer au sud de* Portus *(fig. 1). Cette position particulière s'accompagne aussi d'une réduction graduelle de la largeur des canaux successifs (*Fossa Traiana, Canale Traverso*). Le Tibre, aujourd'hui large de 100-120 m dans le delta était d'une largeur comparable dans l'Antiquité (Le Gall, 1953 ; Bertacchi, 1960). Grâce à la découverte des berges antiques de la* Fossa Traiana *sur plusieurs tronçons mis au jour au XX[e] s., la largeur de ce canal antique est estimée à environ 50 m (Testaguzza, 1970). Enfin, cette largeur se réduit encore pour atteindre 25 m dans le* Canale Traverso*. Chaque embranchement de canal s'accompagne ainsi d'une diminution de moitié de la largeur, réduisant ainsi l'écoulement des eaux fluviales vers les bassins portuaires. Ces données géométriques sont très intéressantes puisqu'elles témoignent sans équivoque de la conscience du problème de l'articulation entre le système portuaire et le système fluvial par les architectes et ingénieurs romains responsables de la construction de* Portus*. Mais cette configuration fut-elle efficace ?*

La carotte CT-1 (fig. 5 et fig. 7), réalisée dans le Canale Traverso*, indique une profondeur de 5,5 m sous le niveau marin antique (calage en référence à J.-P. Goiran* et al.*, 2009). La lame d'eau antique du chenal d'accès au bassin de Trajan se fait plus profonde en direction du bassin de Claude (8 m dans la carotte TR-XI ; Goiran* et al.*, 2010). Dès l'origine, le* Canale Traverso *semble ainsi ne pas avoir été conçu pour recevoir les plus gros navires antiques (Pomey et Tchernia, 1978 ; Boetto, 2010 ; fig. 8). Dans un premier temps, le canal se remblaie très rapidement (2,6 cm/a ; fig. 8). L'enregistrement sédimentaire entre -5,5 et -2,3 m sous le niveau marin antique est composé principalement de vases déposées par suspension uniforme mélangée à des sables déposés par suspension graduée (unités B et C, fig. 5 et fig. 7). Le* Canale Traverso *en fonctionnement offre ainsi un environnement de dépôt calme soumis aux influences marines et fluviales, proche des conditions existant à l'entrée du bassin de Trajan (fig. 6 et fig. 7). L'étude comparée des diagrammes CM des carottes CT-1 et TR-XIV (chenal d'accès au bassin de Trajan ; fig. 7) montre une taille moyenne du* D_{99} *des processus du type 4 (fig. 7), plus élevée dans le* Canale Traverso*. Ce gradient granulométrique atteste ainsi l'apport de sédiments roulés dans le* Canale Traverso *en provenance non pas du port de Claude (sableux), mais du fleuve. La texture restant très fine, ces apports grossiers sont très probablement le résultat d'événements hydrologiques ponctuels comme les crues. Dans le dépôt supérieur du Canale Traverso (de -2,3 m au 0 du niveau marin antique ; CT-1 ; fig. 5 et fig. 8), la présence plus nette de sédiments fluviaux est marquée par une fraction sableuse plus importante. Les conditions de dépôt se produisent plutôt par un mélange de roulement et de suspension graduée et uniforme. Bien que plus grossier, ce remblaiement est en revanche beaucoup plus lent que dans l'unité sous-jacente : 0,45 cm/a (fig. 8). La datation radiocarbone réalisée à environ 1 m sous le niveau marin antique donne la date la plus récente obtenue dans ce secteur de* Portus *et correspond à la fin d'utilisation du* Canale Traverso *: 1415±15 BP, soit 600-660 après J.-C. Ce taux de remblaiement très lent pourrait être expliqué par un (ou plusieurs ?) curage (s) réalisé (s) vers -2,3 m sous le niveau marin antique. Avec une telle lame d'eau, les petits navires de 70 t du type de ceux retrouvés au nord de* Portus *(Boetto, 2006, 2010) pouvaient emprunter le* Canale di Comunicazione Traverso *au plus tard jusqu'au VI[e]-VII[e] s. apr. J.-C.*

Introduction

Portus was the seaport of Rome during the Roman Imperial period. The construction of the harbour began in AD 42 under the reign of the Emperor Claudius. The harbour was located about 3 km north of Ostia, along the Tyrrhenian Coast, but on the margin of the Tiber. A few hundred metres east of *Portus*, the natural Tiber channel curved to the south near Ostia, where it flowed into the sea (fig. 1). At the beginning of the 2nd c. AD, Emperor Trajan complemented the Claudian harbour with a second basin (Juvenal, *Saturae*, XII, 75-78). To date, many sedimentological and palaeoenvironmental studies have been conducted at *Portus*, its basins and its maritime entrances (Arnoldus-Huyzendveld, 2005; Giraudi *et al.*, 2007; Goiran *et al.*, 2007, 2008; Bellotti *et al.*, 2009; Giraudi *et al.*, 2009; Goiran *et al.*, 2010), but much less is known about the fluvial features at *Portus* (Salomon *et al.*, 2010). Inscriptions made during the reigns of Claudius (*CIL* XIV 85 = *ILS* 207) and Trajan (*CIL XIV 88* = *CIL* VI 964 = *ILS* 5797a) were found at *Portus*. They record the digging of canals linking the Tiber River to the sea. Today, a unique canal, the Fiumicino, is visible and still in use on the southern outskirts of *Portus* which was proba-

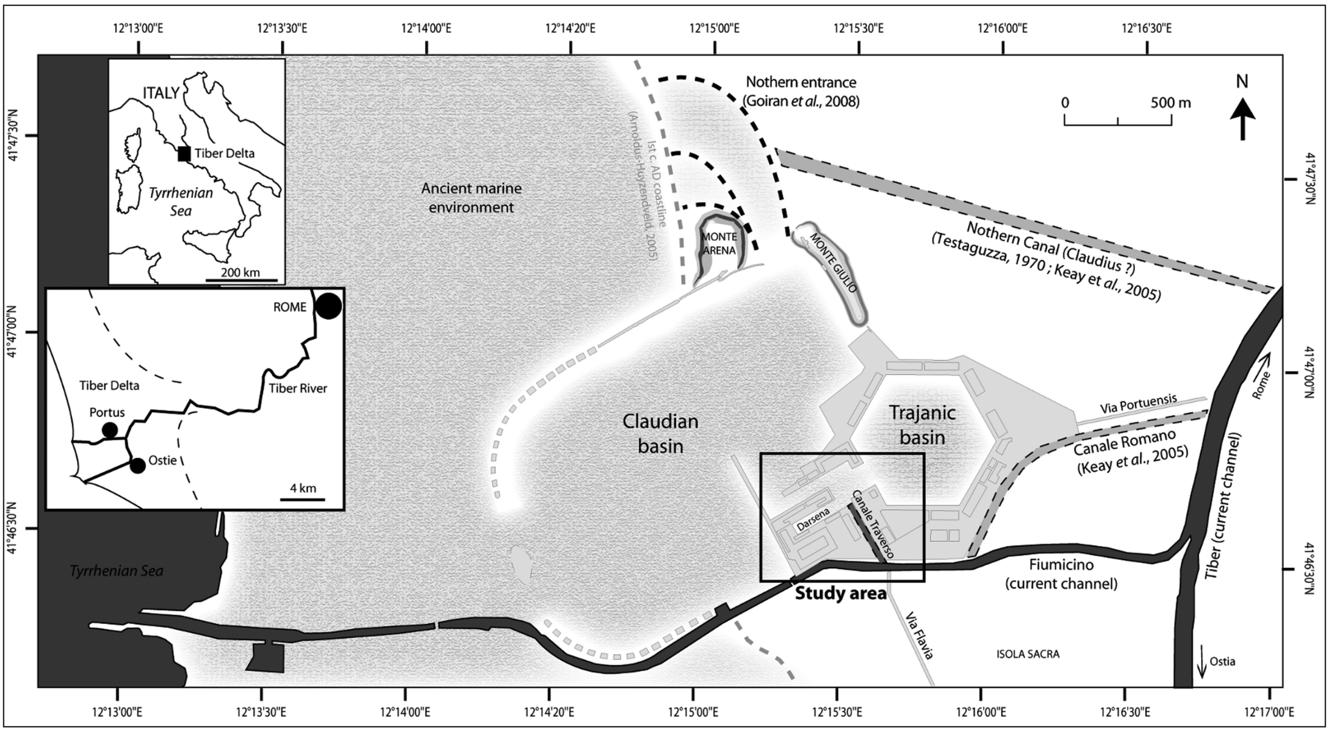


Fig. 1 – **Location map of Portus, the ancient sea harbour of Rome on the margins of the Tiber.**

*Fig. 1 – **Localisation générale de Portus, l'ancien port maritime de Rome en marge du Tibre.***

bly the Roman *Fossa Traiana* (Fea, 1924 a and b). This canal is shown on maps of *Portus* drawn during the Renaissance: for example in a fresco, painted by Ignazio Danti (1582; Galleria delle carte Geografiche of the Vatican Museum). The *Canale di Comunicazione Traverso* was a NNW-SSE channel almost perpendicular to the Fiumicino, which linked this canal to the southern access of the Trajanic basin (fig. 1). It was the only waterway that existed between the sea basins and the fluvial system (Keay *et al.*, 2005). M. Reddé (1986) thinks that the rapid silting up of *Portus*' basins was probably due to fluvial sedimentary input. How did Roman engineers preserve a continuous waterway from *Portus*' basins to the Tiber River without accelerating the rate of siltation in the harbour? Or on the other hand, was this canal able to carry sediment away from the basins thanks to the increase in outflow? Sediment cores, allowed the analysis of the characteristics of the *Canale Traverso* in order to (i) establish its role in the sedimentation of *Portus*' basins and (ii) to define the function and the operation of this canal.

Setting

Geology and geography

The Tiber River, 405 km long from the source to the Tyrrhenian Sea, originates in the Apennine Mountains (Mount Fumaiolo, 1268 m) and drains a 17375 km² basin. The mean annual discharge at the Ripetta gauging station (Rome, 43 km upstream the mouth) is 225 m³/s. The maximum historic discharge exceeds 3000 m³/s and the minimum discharge 60 m³/s. The mean suspended load was 7.2×10^6 t/a at the Ripetta station (1934-1950), before the impacts of large dams on sediment fluxes occurred (Iadanza and Napolitani, 2006).

The Tiber delta has been studied since the 19th c. (Moro, 1871; Ponzi, 1875; Amenduni, 1884; Bocci, 1892), but knowledge on it has improved in the second half of the 20th c. (Dragone *et al.*, 1967). Since the 1980's, deep-coring studies have been completed in order to investigate Holocene stratigraphy (Belluomini *et al.*, 1986; Belfiore *et al.,* 1987; Bellotti *et al.*, 1989, 1994, 1995; Milli, 1997; Amorosi and Milli, 2001; Bellotti *et al.*, 2007). The Tiber delta results from two main influences, a combination of sea and fluvial processes. The rapid sea-level rise from 18000 BP to 7000 BP induced the submersion of the Pleistocene delta. The pace of sea-level rise reduced from 7000 BP to 5000 BP. Consequently, the fluvial sediment input became dominant and the Tiber delta adopted the lobate form, a characteristic of a progradational system (Bellotti *et al.*, 2007). The major migrations of the Tiber channel have been divided into three major phases: (i) During the Late Pleistocene, the palaeo-Tiber flowed into the northern part of the delta (Bellotti *et al.*, 2007); (ii) The second stream way switched to the middle part of the present delta ca. 7000 BP (Bellotti *et al.*, 2007); (iii) During the 9th-8th c. BC, the Tiber mouth moved to the south near Ostia Antica (Giraudi *et al.*, 2009; Bellotti *et al.*, 2011).

Over the past twenty years, a lot of research has been conducted on the late Holocene period aiming to locate the successive Tiber palaeochannels (Segre, 1986; Arnoldus-Huyzendveld and Paroli, 1995; Arnoldus- Huyzendveld and

Pellegrino, 2000), lagoons (Giraudi, 2002; Di Rita *et al.*, 2009; Bellotti *et al.*, 2011) and the coastline variations (Giraudi, 2004; Rendell *et al.*, 2007; Bicket *et al.*, 2009) more precisely. In central Italy, more intense fluvial activity seems to have occurred during Roman Imperial times and reduced during the Late Antiquity and the early Middle Ages (Benvenuti *et al.*, 2006; Bicket *et al.*, 2009). Some of those past hydrological events have been monitored in Rome and have been mentioned by ancient authors (Le Gall, 1953; Bersani and Bencivenga, 2001).

The archaeological area of *Portus* has been the subject of many geoarchaeological and palaeoenvironmental studies. Studies focused on the environments that existed prior to the building of the harbour and on ancient harbour basins (Goiran and Morhange, 2003; Marriner *et al.*, 2010). Pre-harbour aspects have been approached mainly through the study of the migration of the Tiber River in this area of the delta (Segre, 1986, Giraudi *et al.*, 2007; Goiran *et al.*, 2007; Giraudi *et al.*, 2009; Bellotti *et al.*, 2011) and through the position of the shoreline during historical times (Arnoldus-Huyzendveld, 2005). The harbour itself was studied through the reconstruction of basins' shape, and through detailed sediment analysis (Arnoldus-Huyzendveld, 2005; Giraudi *et al.*, 2007; Goiran *et al.*, 2008; Bellotti *et al.,* 2009; Giraudi *et al.*, 2009; Goiran *et al.*, 2010; Sadori *et al.*, 2010). J.-P. Goiran *et al.* (2010) differentiated between sediment deposition in the two basins of *Portus*. The Claudian basin was a poorly protected basin that opened out to the sea; its sediment infill was mostly composed of sands as it was open to the influences of the sea wind and swell. The Trajanic basin was better protected; as a result, its sediment infill was mostly composed of silt and clay (Goiran *et al.,* 2010). In with the continuity of these results, the present work focuses on the origin of sediments in the *Canale Traverso* and Trajan basin.

Archaeology and geoarchaeology

The geoarchaeological work carried out at *Portus* would not have been possible without previous historical and archaeological research (Lugli and Filibeck, 1935; Lanciani, 1868; Testaguzza, 1970; Keay *et al.,* 2005). The available data concerning the geographical units are the following:

- The Fiumicino. In the Late Antiquity, the mouth of the Fiumicino channel was about 2000 m from the Tiber (Procopius, *De Bello Gothico,* 1, 26, 7-13). The western part of the deltaic system has been attributed to the rapid progradation of the coast over the last five centuries (Le Gall, 1953; Giraudi, 2004; Bersani and Moretti, 2008; fig. 1). This canal would have remained navigable until AD 1118 and perhaps even AD 1461 (Coccia, 1993, 2001; Paroli, 2004, 2005). Unfortunately, sedimentary archives have disappeared due to successive operations of dredging. For instance, in AD 1612, the canal was restored to its navigable state when Pope Paul V ordered for it to be dredged (Chiumenti and Bilancia, 1979; Paroli, 2005); also the restoration of the canal banks was implemented in the early 20th c. (Gatti, 1911). In the first monographs on the archaeology of *Portus*, the Fiumicino canal holds a prominent position. In several studies published in the early 19th c., C. Fea (1824 a and b) focused on this channel and identified the Fiumicino canal with the Roman *Fossa Traiana,* an ancient canal of *Portus* cited by Pliny the Younger. For S. Keay *et al.* (2005), the Fiumicino canal dates back to the Claudian period and was later incorporated into the new Trajanic complex.

- The area of the *Canale di Comunicazione Traverso*. The *Canale di Comunicazione Traverso* is a 300 m long and up to 25 m wide channel. This canal is located in an area that was densely occupied after the construction of the harbour from the mid-1st c. AD to the late Middle Ages (Paroli, 2004, 2005). The *Canale Traverso* was probably surrounded by warehouses and storage areas as early as the mid-1st c. AD (Lugli and Filibeck, 1935; Keay *et al.,* 2005). The recent excavation of the *Basilica Portuense* provided extensive data on the evolution of the urban sector. Three chronological phases were identified: (i) the port area which was occupied by administrative and commercial activities, along with warehouses, (ii) at the end of the 3rd and early 4th c. AD, the area became residential, then (iii) between the end of the 4th c. AD and the second half of the 5th c. AD, the basilica was built (Paroli, 2005, p. 258). The archaeological age of the *Canale Traverso* is not currently ascertained by any specific architectural studies. However, based on a study of the visible apparatus (Testaguzza, 1970), the *Darsena-Canale Traverso-Fossa Traiana* complex is thought to have been built at the same time. Thus, the discovery of a brick from Neronian times in one of the Darsena docks dates the *Canale Traverso* back to the 1st c. AD (Keay *et al.,* 2005; Verduchi 2005).

A brief synthesis of palaeoenvironmental analysis

Three recent publications (Goiran *et al.*, 2010; Sadori *et al.*, 2010; Mazzini *et al.*, 2011) develop palaeoenvironmental reconstructions from macrofauna, microfauna (ostracods), and pollen analysis. Ostracod assemblages are related to water salinity (Carbonel, 1980). They are the best indicators to reconstruct marine and fluvial influences on a statistical base. Fig. 3 is a synthesis of J.-P. Goiran *et al.* (2010, in press), and I. Mazzini *et al.* (2011). Results concerning the ostracods groups were simplified into three palaeobiotopes: freshwater, brackish and marine waters. Each circle corresponds to a harbour basin unit defined by respective authors. Fig. 3 clearly indicates the contrast between the Claudian basin, mostly influenced by marine environment (cores CL-7, CL-2 and TR-IV), and the Trajanic channel area, characterised by a brackish palaeobiotope with temporary freshwater influence. Surprisingly enough, the sediment of *Canale Traverso* contains fewer freshwater ostracods (PTS-5) than the Trajanic access channel (TR-XIX, PTS-13) considering the basal layers of the harbour and of the canal during their activity. Could these results allow other freshwater sources to be considered? Indeed, near the TR-XIX core, thermae have been found (Lugli and Filibeck, 1935; fig. 2). The freshwater/brackish signals can

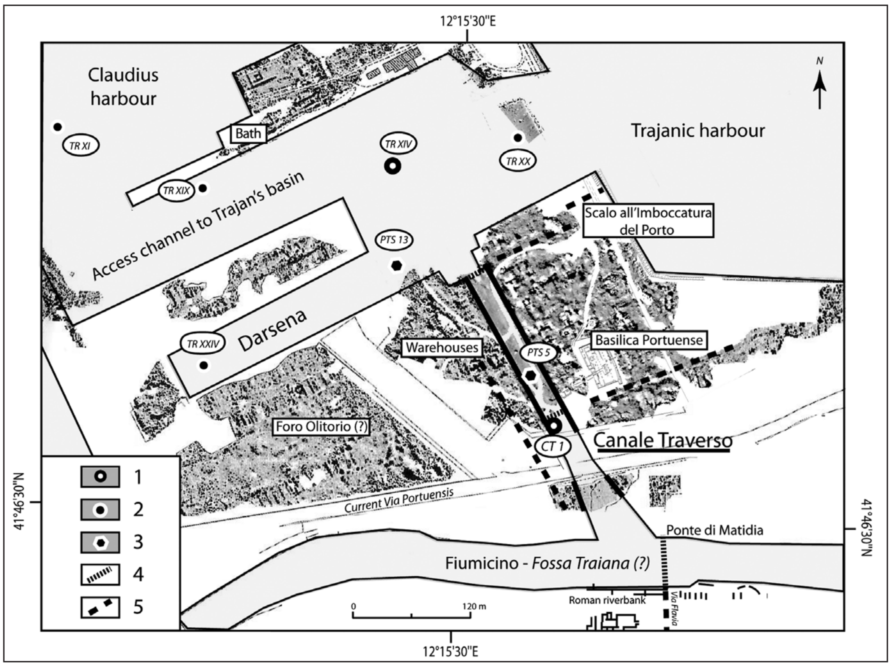


Fig. 2 – **Geomagnetic survey results (Keay *et al.*, 2005) and archaeological data between the Claudius and the Trajan harbour: synthesis of successive cores location near the Canale Traverso.** 1: studied cores in this paper; 2: cores in J.-P. Goiran et al., 2010; 3: cores in C. Giraudi *et al.*, 2009, L. Sadori et al., 2010, I. Mazzini et al., 2011; 4: bridges? (Lanciani, 1866; Keay *et al.*, 2005); 5: streets ? (Keay *et al.*, 2005).

Fig. 2 – ***Résultats des prospections géomagnétiques (Keay** **et al.*****, 2005) et données archéologiques situées entre les bassins portuaires de Claude et de Trajan : synthèse des carottages réalisés à proximité du Canale Traverso.*** *1 : carottages étudiés dans cet article ; 2 : carottages présentés dans J.-P. Goiran* et al.*, 2010 ; 3 : carottages présentés dans C. Giraudi* et al.*, 2009, L. Sadori* et al.*, 2010, I. Mazzini* et al.*, 2011 ; 4 : ponts ? (Lanciani, 1866 ; Keay* et al.*, 2005) ; 5 : routes ? (Keay* et al.*, 2005).*

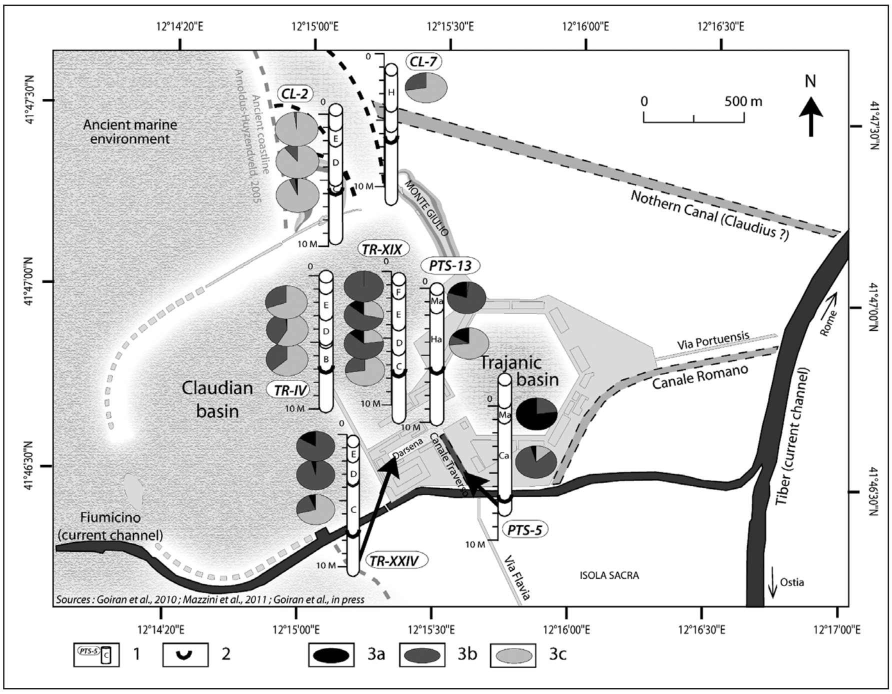


Fig. 3 – **Marine to freshwater palaeoenvironments in the Portus basin obtained by ostracods determination – A synthesis** (Goiran *et al.*, 2010; Mazzini *et al.*, 2011). 1: cores locations with portuary units (Goiran *et al.*, 2009; Mazzini et al., 2011; Goiran *et al.*, in press); all cores are represented according to the 3rd-5th c. sea level (Goiran et al., 2009). Only the portuary units data are shown; 2: harbour bottom; 3: ostracod groups with 3a: freshwater species, 3b: brackish species, and 3c: marine species.

Fig. 3 – ***Synthèse des données paléoenvironnementales obtenues pour les bassins de Portus par détermination de l'ostracofaun****e (Goiran* et al.*, 2010 ; Mazzini* et al.*, 2011). 1 : localisation des carottages avec leurs unités portuaires (Goiran* et al.*, 2009; Mazzini* et al.*, 2011; Goiran* et al.*, sous presse) ; tous les carottages sont représentés en référence au niveau marin des IIIè-Vè apr. J.-C. (Goiran et al., 2009) ; 2 : fond des bassins portuaires ; 3 : ostracodes ; 3a : individus d'eau douce ; 3b : individus d'eau saumâtre ; 3c : individus* caractéristiques du milieu marin.

then be due to inland water discharge from an aqueduct (Keay *et al*., 2005; Bedello-Tata and Bukowiecki, 2006) and not only from the Tiber River through the *Canale Traverso*.

Methods

While recent articles have focused on macrofaunal bioindicators (shells), ostracods and pollen (Giraudi *et al*., 2009; Goiran *et al.,* 2010; Sadori *et al*., 2010; Mazzini *et al*., 2011), this paper focuses on granulometric data and possible river influence on the canal. Core locations are presented on the fig. 2 with results of the geomagnetic survey obtained by fluxgate radiometer and published in S. Keay *et al*. (2005).

Cores presented were collected using a mechanical rotary core barrel during several field excursions from 2004 to 2009. The objective of coring TR-XIV and CT-1 was to accurately characterise the sedimentary sequences of the access channel to the Trajanic basin and the *Canale Traverso*. Thus, the cores are around 10-m deep and include the complete harbour and canal sedimentation sequence. The cores were analysed in the OMEAA laboratory in Lyon.

Magnetic susceptibility was measured three times every centimetre using a Bartington MS2E1 (Dearing, 1999). The value of susceptibility is recorded in CGS (centimeter, gram,

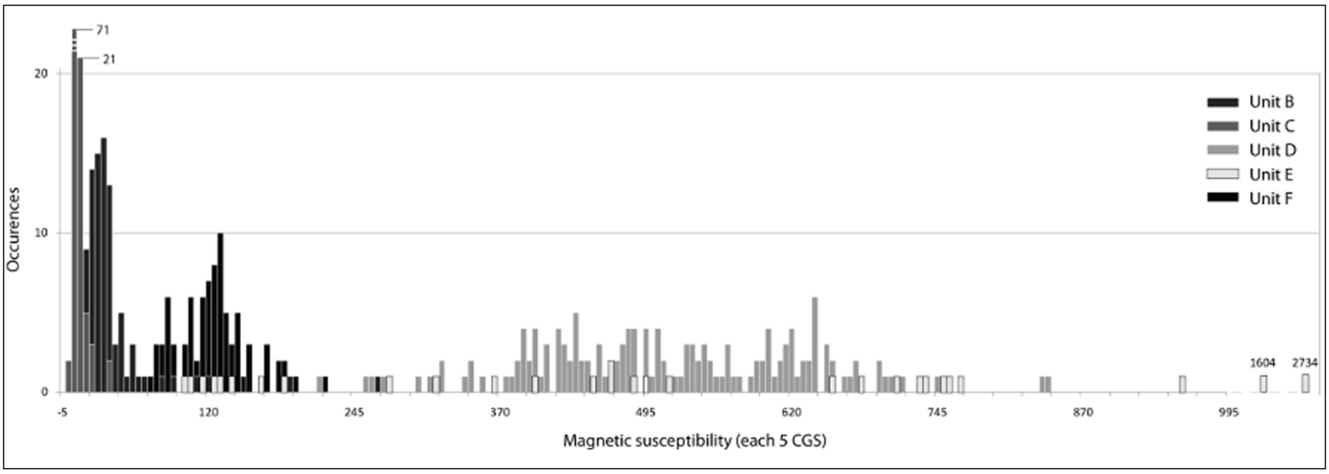


Fig. 4 – **Magnetic susceptibility results for core CT-1 - Relevance of a high-resolution dataset (each centimetre) to determine sedimentary layers.** Bars are grouped by sedimentary units and correspond to the occurrence of MS data (y-axis) included in a range of 5 CGS (x-axis).

*Fig. 4 – **Résultats de susceptibilité magnétique pour le carottage CT-1.** Ce graphique valide la pertinence des données de haute résolution (chaque centimètre) pour définir des unités sédimentaires. Les barres sont identifiées selon les unités sédimentaires et correspondent à l'occurrence des valeurs de SM (en ordonnée) incluses dans un intervalle de 5 CGS (en abscisse).*

second system) unit (corresponding to SI = CGS value * 0.4; Dearing, 1999). This non-destructive method efficiently separates different sedimentary units (Dearing, 1999), as attested in fig. 4 with a histogram depicting the CT-1 core. One colour rectangle corresponds to each unit. The x-axis represents the magnetic susceptibility in each 5 CGS. The occurrences of MS values in this range of 5 CGS are shown on the y-axis (fig. 4). Magnetic susceptibility offers a range of values with fairly consistent distributions for low values, but very large distributions for high values. Corresponding to the magnetic susceptibility, densitometric analysis was undertaken using an X-ray-scanner. Based on this high-resolution analysis, we sampled every 3 cm to 10 cm. Then, depending on sedimentary facies, we analysed a sample every 10 cm to 40 cm.

Then, to get an overview of the texture of each of these samples, we sieved 30 g of the total fraction to distinguish between silt-clay (<63 μm), sand (63 μm-2 mm) and coarse fraction (>2 mm). Finally, on the sediment fraction <1.6 mm, accurate granulometrical analysis was undertaken using a *Malvern Mastersizer 2000*. Trask sorting index and the median grain have been used to describe the grain size distribution (Folk and Ward, 1957; Rivière, 1977). The interpretation of granulometric curves was based on the CM diagram, also called the Passega image (Passega, 1957; Bravard, 1983; Arnaud-Fassetta, 1998; Bravard and Peiry, 1999; Arnaud-Fassetta *et al.,* 2003). This diagram uses the median (D_{50}) and the coarsest percentile (D_{99}) to determine depositional and transport processes.

During this study, we used the biological mean sea level as determined on the quay of *Portus* (Goiran *et al*., 2009). It corresponds to the upper biological limit of barnacles dated at 2115±30 BP, calibrated AD 230-450. This biological, Roman sea level (R.s.l.) stands 0.8 m below the current biological sea level (Goiran *et al*., 2009). The studied cores are related to those current and R.s.l. This article will deal especially with the period from the 1st to the 7th c. AD. During this period, the sea level may have changed a few centimetres above and below the sea level of the 3rd-5th c. AD (Goiran *et al*., 2009). We do not exclude the possibility of limited compaction of the harbour sedimentary sequence, but without consequences for our interpretations.

In order to establish an age-depth model, five radiocarbon dates were obtained on core CT-1. We focused on dating

Samples	Laboratory samples	Sample description	Activity (in %)	Radiocarbon dating (in years BP)	Age calibated *(Reimer* et al., 2004) - 2σ
CT1-A (344)	Lyon-6869	Charcoal	83.84 ± 0.25	1415 ± 30	600 to 660
CT1-C (554)	Lyon-7081	Wood	4.00 ± 0.26	1830 ± 30	90 to 245
CT 1-E (737)	Lyon-6894	Charcoal	78.54 ± 0.23	1940 ± 30	5 to 125
CT 1-G (792)	Lyon-6895	Seed	78.76 ± 0.23	1920 ± 30	25 to 130
CT1-B (1158)	Lyon-6870	Charcoal	60.55 ± 0.21	4030 ± 30	-2620 to -2475

Tab. 1 – **Radiocarbon dating results.**

*Tab. 1 – **Résultats des datations par le radiocarbone.***

wood fragments, charcoal and seeds using the AMS dating technique. Calib 6 software was used for calibrating dates (tab. 1) with the continental curve (Reimer *et al*., 2004). A margin of error of 2 sigma was retained.

Results

The detailed description of cores CT-1 and TR-XIV is presented below:

CT-1: Canale Traverso (fig. 5 and fig. 7)

This sedimentary core focuses on the granulometric description. For more information about microfauna and pollen content of core PTS-5 (fig.2), we refer the reader to L. Sadori *et al*. (2010) and I. Mazzini *et al*. (2011).

- Unit A is composed of yellow sterile layered sands (82%). The silt and clay fraction corresponds to 18% of the total dry sample. The sediment is moderately well sorted with a mean Trask index of 2. The median grain size of this unit is the highest of the whole sedimentary sequence (197 μm), but it rises progressively from the bottom of the core around 100 μm (graded suspension at a depth of 1183 cm, type 1) to 354 μm (medium sand) at the top (dominance of graded suspension and rolling, type 2). A layer at the bottom of the sequence is composed mostly of silts and clays (65%) with a median grain size around 13 μm. This sandy-silt layer has a coarse fraction with plant remains and seeds. A piece of charcoal has been dated to 4030±30 BP (2620-2475 BC). The global magnetic susceptibility value (MS) of this unit is around 156 CGS, ranging between 34 and 378 CGS.

- Units B and C are composed of dark grey mud with shells and *Posidonia,* which is a marker of the marine influence. 95% of unit B is composed of silt and clay, a value reduced to 84% in unit C. The average median grain size for most of sequence B and C ranges between 10 μm and 13 μm. These units are characterised by a poor sorting index (mean of 3.5). The depositional processes point mostly to mixed graded and uniform suspensions (type 3 on the CM diagram; fig. 7). However, in units B-C, sample '741' is a mix of rolled particles and graded/uniform suspension (type 4). The organic content of units B and C is high (10% of the dry weighted sediment). The coarse faction (>2 mm) is composed of shell fragments, clasts (rolled and not rolled), plant remains, charcoal, wood fragments and *Posidonia*. Seeds and charcoal have been radiocarbon dated 1920±30 BP (AD 25-130; Lyon-6895) and 1940±30 BP (AD 5-125; Lyon-6894) respectively, at the bottom of unit B. In the middle of unit C, a fragment of wood has been dated 1838±30 BP (AD 90-245; Lyon-7081). The mean MS is higher in unit B (38 CGS), than in unit C (9 CGS).

- The sedimentary facies of unit D is a grey sandy-silt with shells and artefacts. Compared to unit C, a larger proportion of the dry weight sediment is composed of sand (31%) and coarse fraction larger than 2 mm (19%). The median grain size is very fine sand (67 μm). The sediment of unit D is very poorly sorted (mean of 5.6). Depositional processes are dominated by a mix of rolling and graded suspension (type 4); a mix of graded and uniform suspension (type 3) is represented in the lower part (sample '433', type 3). We can observe a progressive decrease in the percentage of the organic material from 8.5% at the bottom to 5.6% at the top. Fragments of shells, clasts, wood fragments, vegetation remains, a lot of potshards and some *Posidonia* are present at the bottom of unit D. A later date has been obtained from a piece of charcoal: 1415±30 BP (AD 600-660; Lyon-6869). The MS value increases significantly to a mean of 512 CGS, ranging between 192 CGS and 842 CGS.

- Units E and F (-68 cm to 180 cm in reference to the current sea level) are yellow sandy silt to laminated silt. The fine fraction increases from 67% (unit E) to 85% (unit F). The sorting index is low but slightly higher than in the lower units (4 to 3.6). The organic matter content decreases (5.14% to 3.2%). The depositional processes are mixed (types 3 and 4), even if some layers belong to the uniform suspension (type 5). The MS values are around 600 CGS.

TR-XIV: Access channel to the Trajanic basin (fig. 6).

- Unit A is yellow sterile layered sand similar to unit A at the bottom of the CT-1 core. Sand is dominant, deposited as graded suspension (type 1), with a median grain size between 90 μm and 120 μm. The organic content is low (1.3%). The mean magnetic susceptibility value is 46 CGS.

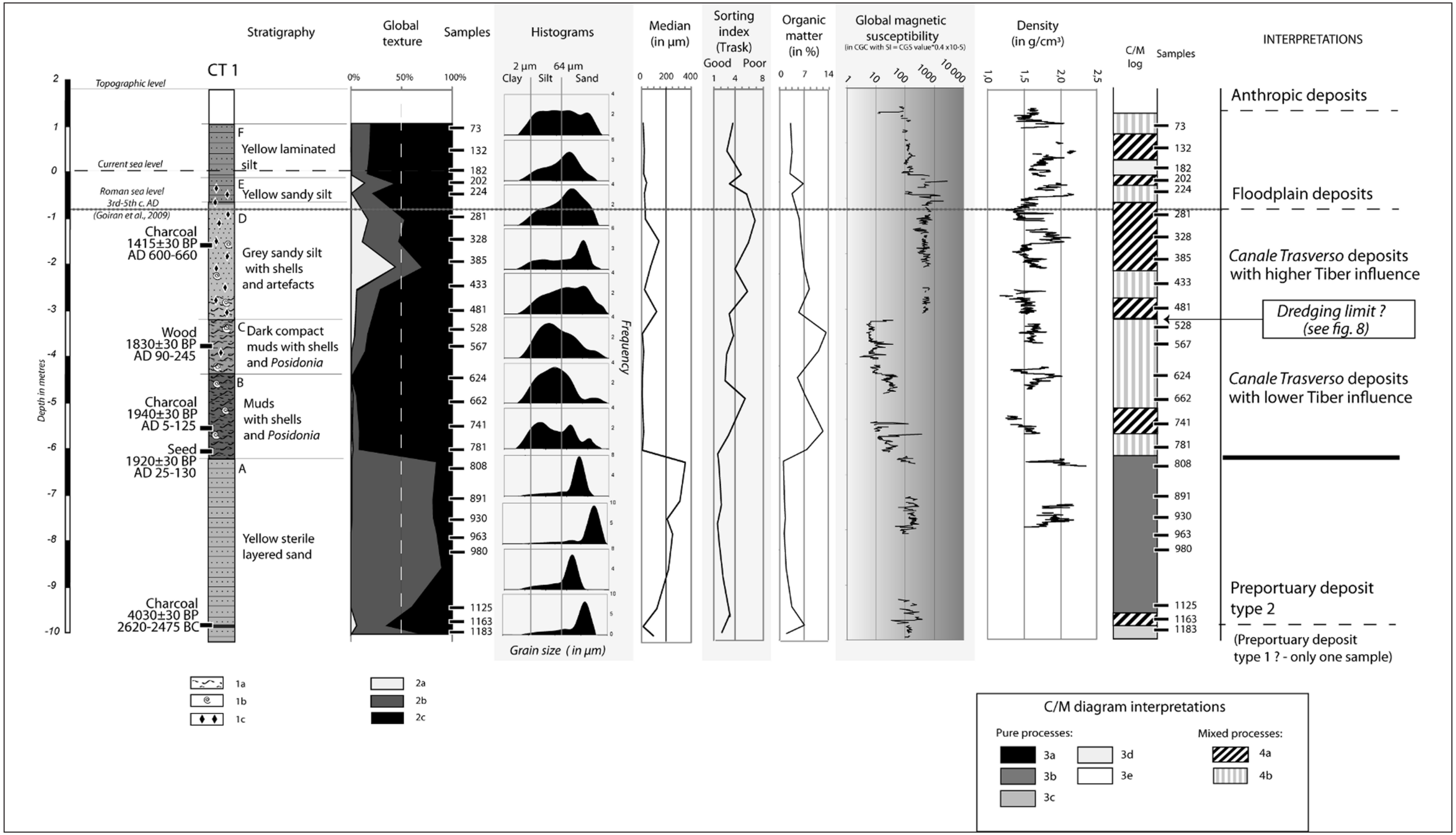
- The sedimentary environment changes abruptly since units B and D are composed of mud and sandy-mud with shells and *Posidonia* with 85% of fine sediments (<63 μm). They are characterised by a negative magnetic susceptibility around -25 CGS. The average median grain size is 13 μm. Compared to unit A, the organic matter content is multiplied by 6 with a maximum of 12%. The environment was relatively quiet with a mix of uniform and graded suspension processes (type 3). Between these two units, a sandy layer (70% of sand in unit C) was deposited by mixed rolling and graded suspension processes (type 4). The magnetic susceptibility increases to 30 CGS, in positive values. Sparse potshards have been collected in unit D.

- Units E and F are quite similar to units B and D, but with a smaller proportion of fine sediments (78%) and a greater proportion of organic matter (up to 22%). Shells and *Posidonia* are more present. The dominant depositional processes are a mix of uniform and graded suspension. The major difference between the sedimentary units are given by the values of magnetic susceptibility. Unit F has similar negative value, around -5 CGS, contrasting with unit E characterised by positive values with a mean of 7 CGS.

- Units G and H are mostly composed of fine sediment (73%) but, between these two layers, the sandy content is similar to the fine fraction. A high frequency of shells has been observed in this intermediate level. In unit G the sandy content was deposited by mixed rolling and graded suspension processes increased. The magnetic susceptibility is positive with a mean value of 7 CGS. The sand content decreases in unit H which displayed a quieter environment with uni-

Fig. 5 – **Canale Traverso, analysis of the core CT-1.** 1a: Posidonia; 1b: shells; 1c: pot shards; 2a: coarse sediments; 2b: sand; 3c: silt and clay; C/M diagram interpretation. 3: pure processes: 3a: rolling; 3b: rolling and graded suspension; 3c: graded suspension; 3d: uniform suspension; 3e: decantation; 4: mixed processes: 4a: mixed rolling/graded suspension + uniform suspension; 4b: mixed graded + uniform suspension.

*Fig. 5 – **Le Canale Traverso, analyse de la carotte CT-1.** 1a : Posidonie ; 1b : coquille ; 1c : céramique ; 2a : fraction grossière ; 2b : sables ; 3c : limons et argiles ; Interprétation du diagramme C/M. 3 : processus purs : 3a: roulement ; 3b : roulement et suspension graduée ; 3c : suspension graduée ; 3d : suspension uniforme ; 3e : décantation ; 4 : processus mixtes : 4a : roulement/suspension graduée + suspension uniforme mixés ; 4b : suspension graduée et uniforme mixées.*



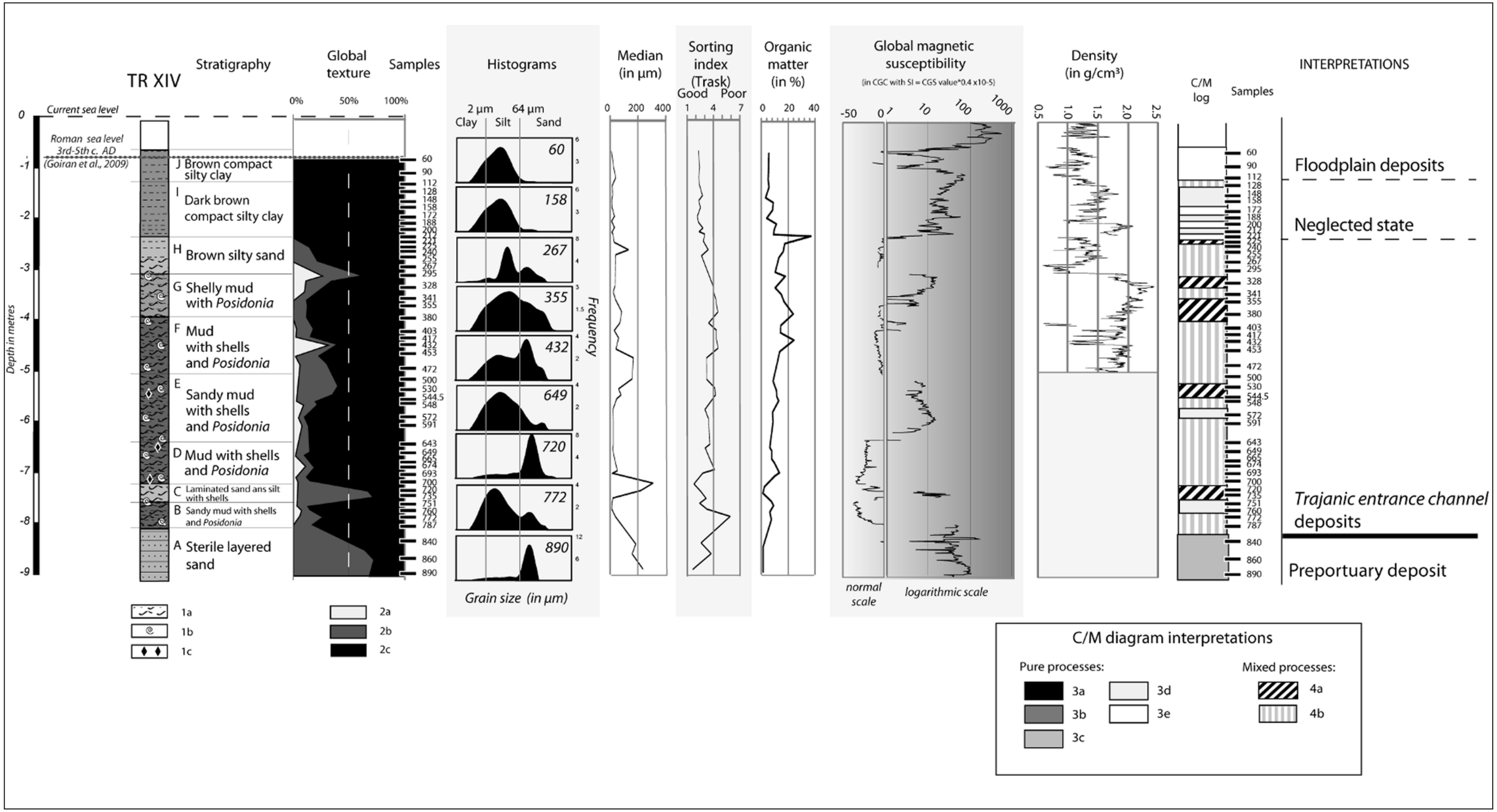


Fig. 6 – **The access channel to the Trajanic harbour, analysis of core TR-XIV.** 1a: Posidonia; 1b: shells; 1c: pot shards; 2a: coarse sediments; 2b: sand; 3c: silt and clay; C/M diagram interpretation. 3: pure processes: 3a: rolling; 3b: rolling and graded suspension; 3c: graded suspension; 3d: uniform suspension; 3e: decantation; 4: mixed processes: 4a: mixed rolling/graded suspension + uniform suspension; 4b: mixed graded + uniform suspension.

*Fig. 6 – **Le chenal d'accès au port de Trajan, analyse de la carotte TR-XIV.** 1a : Posidonie ; 1b : coquille ; 1c : céramique ; 2a : fraction grossière ; 2b : sables ; 3c : limons et argiles ; Interprétation du diagramme C/M. 3 : processus purs : 3a: roulement ; 3b : roulement et suspension graduée ; 3c : suspension graduée ; 3d : suspension uniforme ; 3e : décantation ; 4 : processus mixtes : 4a : roulement/suspension graduée + suspension uniforme mixés ; 4b : suspension graduée et uniforme mixées.*

form and graded suspension mixing processes and with a low magnetic susceptibility (mean of -3 CGS).

- The two upper layers (units I and J) are characterised by layers of silt and clay deposited by alternated uniform suspension and decantation. More than 99% of the total fraction is composed of fine fraction. In unit I, the magnetic susceptibility increases from 10/20 CGS at the bottom to 60 CGS at the top. Finally, those values in unit J are highly variable.

Discussion

The analysis of the two studied cores allows us to determine three sedimentary phases: the pre-harbour environments, the harbour and canal in activity, and the final infill.

Pre-harbour deposits

In the CT-1 and TR-XIV cores, basal units A correspond to pre-harbour deposits characterised by yellow sterile layered sands. In support of this interpretation, a piece of charcoal sampled 10 m below current sea level has been dated 4030±30 BP (2620-2475 BC). The sediment facies is similar to all the *Portus*' basal units (Goiran *et al.,* 2010, in press). On the Passega diagram, sediments plot parallel to the straight line of perfect sorting C (D_{99}) = M (D_{50}). Depositional processes correspond to graded suspension (type 1) and rolling (type 2; fig. 7).

The Canale Traverso geometry and location as evidence of Roman planning

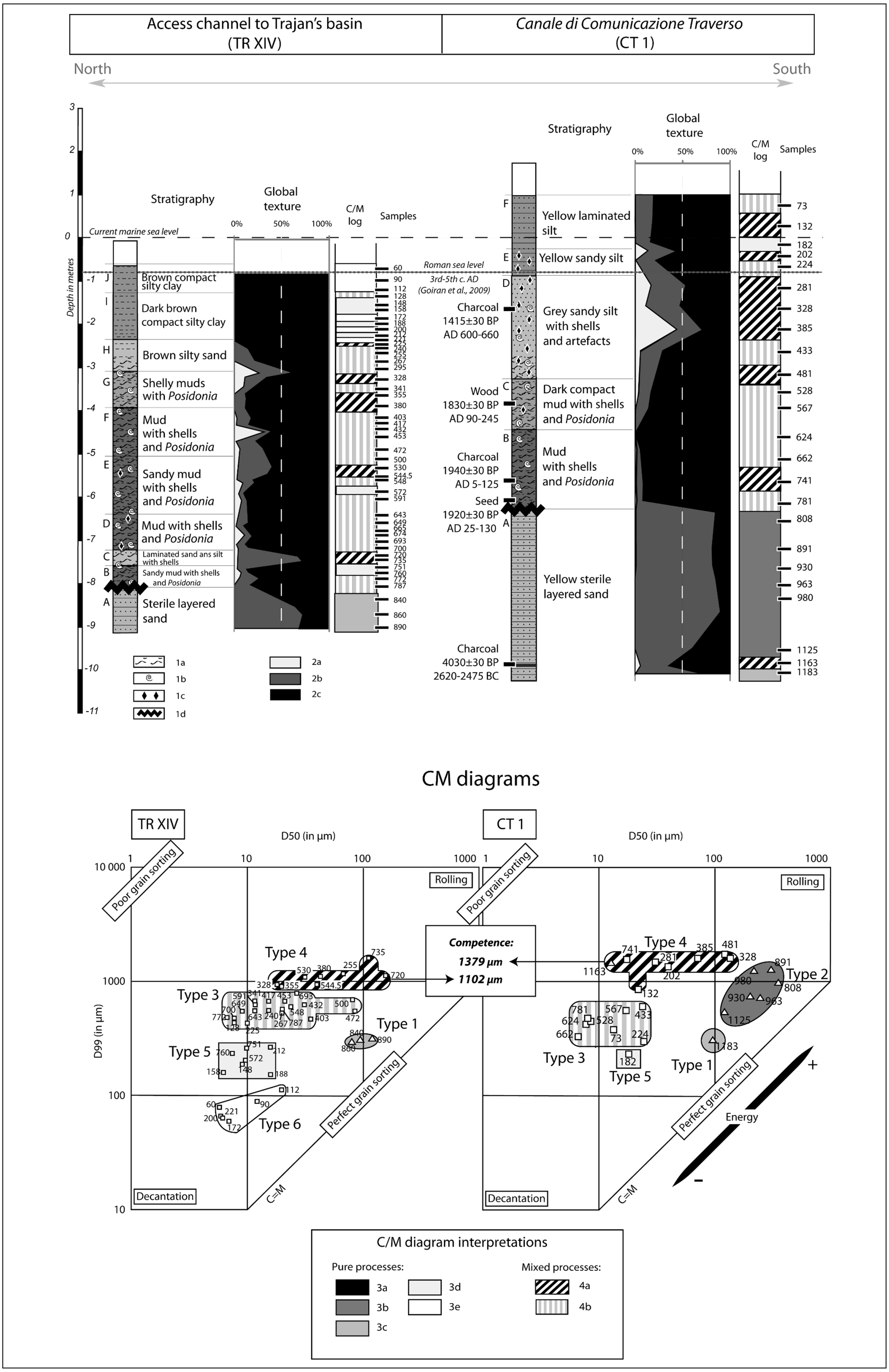
This channel is relatively narrow compared to other channels of the *Portus* complex. After re-analysing the results of a geomagnetic survey (Keay *et al*., 2005; fig. 2), it seems pretty clear that the channel widens towards the *Fossa Traiana*, thus facilitating the movement of ships entering this channel. On the side of the docks, the canal opens into an approximately 40-m wide space, opened to the north. Strong brick walls, over 3-m high (4 m above the Roman sea level) are still visible today. In an upstream-downstream perspective (from the Tiber channel to the *Canale Traverso*), it can be hypothesised that there is a progressive reduction of the hydraulic cross section and of the flow along the derivation canals (fig. 1). The natural Tiber channel was 100 m to 120 m wide in the 1st c. AD, which is confirmed by L. Bertacchi (1960) in the former Tiber channel or Fiume Morto near Ostia. The ancient *Fossa Traiana* was around 50-m wide (Testaguzza, 1970). Finally, the *Canale Traverso* was 25-m wide (see magnetical survey in S. Keay *et al*., 2005). In the successive reaches of the canals (*Fossa Traiana, Canale Traverso*), widths were divided twice into two. We cannot precisely locate the palaeochannel of the Tiber near ancient *Portus*, but in a logical upstream and downstream continuity, the water in the *Canale Traverso* would have flowed perpendicular or in the opposite direction of flow of the palaeo-Tiber. In this deltaic plain, the flow of water in the *Canale Traverso* should be small. This geometric data is interesting because it may demonstrate a clear awareness of the problem arising when planning the position of the port and of the river system by the ancient architects and engineers responsible for the construction of *Portus*. We are now able to see how through a succession of canals and thanks to their optimal orientation, Romans tried to reduce the carrying capacity of the channel entering into the harbour basins, while ensuring the presence of a waterway between the river and the harbour. However, one question remains unanswered: was this configuration effective against sedimentation?

Harbour and canal sedimentation occurred in a common quiet brackish environment

The katolimenic limit corresponds to the bottom of a harbour sedimentary sequence (Goiran *et al*., 2010), between pre-harbour deposit (the yellow sterile layered sand) and the harbour mud, characteristic of a quiet environment protected from the sea's influence. In the TR-XIV core, the first potshards were found in unit D. Thus at this location, the channel access to the Trajanic harbour is 7 (unit B) or 6.5 (unit D) meters deep below the R.s.l. From 7 m to 3.30 m below R.s.l. (unit B to H), the sedimentary sequence of the TR-XIV core is mostly composed of muds with shells and *Posidonia* fibers. The harbour deposits of the TR-XIV core correspond to the other cores described in this area of *Portus* and deposited under high marine influence (cores TR-XIX, TR-XX in Goiran *et al.,* 2010). The environmental conditions under which deposition occurred were relatively quiet, with a mix of graded and uniform suspension processes. Some levels display energetic hydrodynamic condition with sediment originating from a mix of graded and rolling processes. These sandy units occur mostly in units C, E and G. The *Canale Traverso* is only 5.5 m below R.s.l. (CT-1). It is an unusual fluvial canal because it has conditions similar to those of a harbour basin. Indeed, units B and C are composed of mud with shells and *Posidonia*, corresponding to the first phase of deposition. The depositional processes are primarily represented by mixed uniform and graded suspension, similar to those of core TR-XIV. The presence of *Posidonia* validates the hypothesis of the marine influence in the canal, succeeded by a brackish

Fig. 7 – **Cross-sections from the Canale Traverso to the access channel to Trajanic harbour, and CM diagram of the CT-1 and TR-XIV cores.** 1a: Posidonia; 1b: shells; 1c: pot shards; 1d: canal or harbour basin bottom; 2a: coarse sediments; 2b: sand; 3c: silt and clay; C/M diagram interpretation. 3: pure processes: 3a: rolling; 3b: rolling and graded suspension; 3c: graded suspension; 3d: uniform suspension; 3e: decantation; 4: mixed processes: 4a: mixed rolling/graded suspension + uniform suspension; 4b: mixed graded + uniform suspension.

Fig. 7 – ***Transect longitudinal du Canale Traverso au chenal d'accès au basin de Trajan. Présentation des diagrammes CM pour les carottages CT-1 et TR-XIV.*** *1a : Posidonie ; 1b : coquille ; 1c : céramique ; 1d : fond du canal ou du port ; 2a : fraction grossière ; 2b : sables ; 3c : limons et argiles ; Interprétation du diagramme C/M. 3 : processus purs : 3a: roulement ; 3b : roulement et suspension graduée ; 3c : suspension graduée ; 3d : suspension uniforme ; 3e : décantation ; 4 : processus mixtes : 4a : roulement/suspension graduée + suspension uniforme mixés ; 4b : suspension graduée et uniforme mixées.*


Access channel to Trajan's basin (TR XIV)
Canale di Comunicazione Traverso (CT 1)
North
South
Depth in metres
Current marine sea level
Roman sea level 3rd-5th c. AD (Goiran et al., 2009)
Stratigraphy
Global texture
C/M log
Samples
0%
50%
100%
J Brown compact silty clay
I Dark brown compact silty clay
H Brown silty sand
G Shelly muds with Posidonia
F Mud with shells and Posidonia
E Sandy mud with shells and Posidonia
D Mud with shells and Posidonia
C Laminated sand ans silt with shells
B Sandy mud with shells and Posidonia
A Sterile layered sand
F Yellow laminated silt
E Yellow sandy silt
D Grey sandy silt with shells and artefacts
C Dark compact mud with shells and Posidonia
B Mud with shells and Posidonia
A Yellow sterile layered sand
Charcoal 1415±30 BP AD 600-660
Wood 1830±30 BP AD 90-245
Charcoal 1940±30 BP AD 5-125
Seed 1920±30 BP AD 25-130
Charcoal 4030±30 BP 2620-2475 BC
1a
1b
1c
1d
2a
2b
2c
CM diagrams
TR XIV
CT 1
D50 (in µm)
D99 (in µm)
Rolling
Poor grain sorting
Perfect grain sorting
Decantation
C=M
Competence:
1379 µm
1102 µm
Type 1
Type 2
Type 3
Type 4
Type 5
Type 6
Energy
+
-
C/M diagram interpretations
Pure processes:
Mixed processes:
3a
3b
3c
3d
3e
4a
4b

environment with a freshwater input (Mazzini *et al*., 2011). Most significantly, the fluvial influence is deduced from the presence of *Alnus* pollen which were found trapped inside the sediments, and probably transported and deposited there by the Tiber (Sadori *et al*, 2010). The bottom of this canal sediment has been dated from the 1st c. to the beginning of the 2nd c. (seed-Lyon-6895/charcoal-Lyon-6894). Unit C is dated from the end of the 1st c. AD to the middle of the 3rd c. AD (wood-Lyon-7081). It is impossible to specifically date the construction of the canal between Claudius and Hadrian reigns. Whatever the answer, the basal unit B and probably unit C correspond to the first canal deposits.

Last sedimentation of Portus waterways

The closely related evolution, as described in the first metre of the canal's sediments infill (CT-1) and the access channel to the Trajanic harbour (TR-XIV), are not characteristic of the upper units. Unit D of the *Canale Traverso* demonstrates an increase in hydrodynamism, shown by a coarser median grain size (10-13 μm to 67 μm). The mixed processes of graded suspension and rolling are dominant. This layer has not been found in the TR-XIV core which displays constant conditions from unit B to unit H, with mixed uniform and graded suspension. In unit D of the CT-1 core, one meter below the former R.s.l., a piece of charcoal has been dated to the 7th c. AD (charcoal-Lyon-6869). Unfortunately, no dating was possible in the access channel above -3 m (R.s.l). However, on the fresco painted by Ignazio Danti in 1582, the southern end of the *Canale Traverso*, close to the Fiumicino canal, is plugged by sediments, and stagnant water is visible in the access channel which is both disconnected from the sea and the fluvial system. The upper units of the CT-1 core can be interpreted as the deposition of this upstream sediment blockage. In the same way, the upper units I and J of the TR-XIV core correspond to swamp and floodplain deposits, showing the alternation of uniform suspension and decantation processes. These deposits correspond to the upper part of the PTS-5 and 13 cores (Mazzini *et al*., 2011; fig. 3), with a high frequency of freshwater ostracods groups.

A canal and a harbour silted up with sediment transported by Tiber River floods?

When operational, the *Canale Traverso* was a quiet environment similar to the environments present at the entrance of the Trajanic harbour. Another fundamental question is whether mixed rolling and graded suspension results from a marine origin (Claudius basin) or from a fluvial origin. In the CM diagram, the mean coarsest grain-size percentile (D_{99}) present in type 4 indicates the maximum transport capacity of particles. This mean D_{99} grain of the CT-1 core is coarser (1379 μm) than the mean D_{99} of the TR-XIV core (1102 μm), with rolled particles. Therefore, it is hypothesised that there is an influence of the Tiber River's flow (floods in particular) in the *Canale Traverso* (fig. 7). In this area, future work will ascertain whether fine sediments originate mainly from the Tiber River through the *Canale Traverso*. A preliminary answer is that the sedimentation rate in the bottom units of the *Canale Traverso* is higher than in the access channel to the Trajanic harbour (fig. 8; Goiran *et al.,* 2010). So far, it is risky to attribute the presence of flood deposits in the *Canale Traverso* to a regional hydroclimatic crisis context. Indeed this canal is a specific sediment trap mainly controlled by anthropic influences. Besides, at a certain period, a canal lock may have been installed between the *Fossa Traiana* and the *Canale Traverso* (Testaguzza, 1970).

Water depth and boat draughts

Fig. 8 synthesises all the published radiocarbon data concerning the access channel to Trajan's basin in relation to the R.s.l. (Goiran *et al.,* 2009, 2010). These dates are confronted by the altitudinal variations of the bottom of the harbour, called 'mesolimenic limit' (Goiran *et al*., 2010), and also to different Roman boat draughts (Boetto, 2010). To compute the sedimentation rate, we used the mean radiocarbon date. First of all, the *Canale Traverso* was not deep when it was excavated (5.5 m), while the access channel to the Trajanic basin was 6.8 m (TR-XX), 7 m (TR-XIV) to 8 m (TR-XI) deep (Goiran *et al.,* 2010; fig. 8). Thus, a slope from the *Canale Traverso* to the Claudian basin may be deduced from these data. Thus, when it excavated, the canal was probably designed to accommodate vessels with a shallow draughts (fig. 8). This result is synonymous with the relatively limited width of the canal (25 m; Boetto, 2006, 2010). Using the radiocarbon dates, the sedimentation rate may be divided into two phases. In the TR-XI core from -8 m to -6 m (R.s.l.), the bottom of the access channel aggraded by approximately 1.1 cm/a. The two first metres of TR-XX (from 6.8 m to 4.3 m below R.s.l.) aggraded faster than TR-XI, at a rate of 1.6 cm/a. Finally, the CT-1 core displays a fast accretion rate (2.6 cm/a) for the bottom 2.3 m. It can be deduced that in the access channel to the Trajanic basin, the closer to the *Canale Traverso*, the faster the accretion of the bottom of the channel. This observation can also apply to the river sediment supply which originated from the Tiber River. The second aggradational phase is more differentiated. The channel bottoms of TR-XI and TR-XX aggraded at a higher rate from 1.6 cm/a (TR-XX -6 m to -3 m R.s.l.) to 4.2 cm/a (TR-XI -4.3 m to -3 m R.s.l.). An inversion of dates occurs in the TR-XI core and could be interpreted as a phase of dredging (Marriner and Morhange, 2006). Unfortunately, there is no date for the last 3 m (R.s.l.) inside the access channel to Trajan's basin. After a first phase of rapid siltation in the canal (2.6 cm/a), the second phase displays a slower rate of sedimentation with coarser sediments (0.45 cm/a). Theoretically, the canal would have filled with sediments becoming finer at the top of the sequence. In reality, sediment is coarser than below, with a reduction in the rate of siltation. The canal may then have been dredged at the base of Unit D (the abrupt change in magnetic susceptibility could

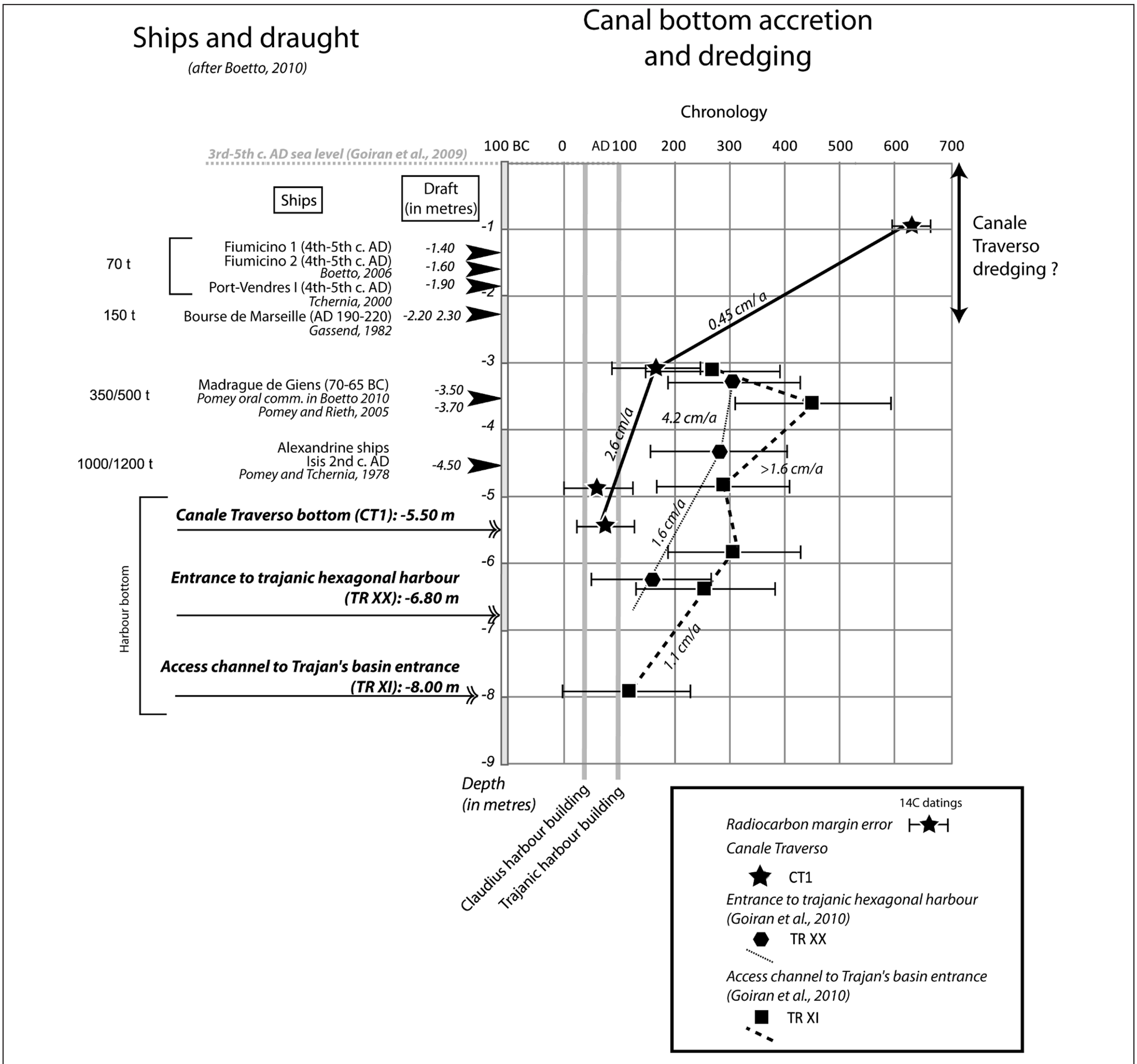


Fig. 8 – **Harbour infill, water depth and ships draught data. Comparisons of these parametres by chronology.**

Fig. 8 – ***Compilations des données disponibles à Portus pour comprendre chronologiquement la relation entre le remblaiement du port, la lame d'eau disponible et le tirant d'eau des bateaux.***

be reconciled with that location). If the depth of the canal is maintained by dredging at about -2.3 m below the Roman sea level, small boats (70 t), like those found in the northern part of Claudius harbour (Boetto, 2006), could have navigated along this canal before the 7th c. AD. At the beginning of the 5th c. AD, Philostrogius (*Ecclesiastical History,* XII, 3 in Le Gall, 1953) described three basins in *Portus*, probably the Claudius and Trajanic basins, along with the *darsena* (Le Gall, 1953). Also Philostrogius specified that the *Fossa Traiana* was the middle of the port. He may have seen the *Canale Traverso*, originating from the *Fossa Traiana,* flowing into the access channel between the Claudius and Trajanic basins on one side and the *darsena* on the other side.

Conclusions

The relationship between ancient harbour basins and the fluvial system of the Tiber delta is a complex and crucial question. This paper takes advantage of the plurality of studies published on *Portus* in the recent years. In a new perspective, the history, harbour and naval archaeology, fluvial and ancient harbour geoarchaeology, were combined with new palaeoenvironmental studies in order to give a renewed description of *Portus* basins. Environmental and depositional conditions are quite similar at the entrance of the Trajanic basin and in the *Canale Traverso*. Granulometrical analyses provided new CM diagrams (Passega) about the conditions of sediment deposition in the harbour, with a wider range of processes in the access channel to Trajanic harbour (TR-XIV). The *Canale Traverso* is prone to higher energy flows coming from the Tiber (CT-1). This approach allows at better understanding of sediment budgets and functioning in the *Portus* harbour. Obviously, the basins silted up inexorably, despite the initial project of reducing sediment input from the Tiber. The sediment budget depended on preventive actions (*e.g.*, geometry and configuration of the canals sheltered from the Tiber flow direction; or maybe canal lock in the *Canale Traverso* according to Testaguzza, 1970), on adaptive actions (*e.g.*, construction of internal moles; Lugli and Filibeck, 1935; Keay *et al.*, 2005) and curative actions (dredging). Future research may provide a more accurate vision, in particular the modelling of the waterflow in *Portus* and in the canals. Finally, the *Canale Traverso* is the starting point for future research on the canals directly connected to the Tiber, like the *Canale Romano* and the Northern Canal (Keay *et al.*, 2005; Salomon *et al.,* 2010).

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