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The Upper Pleistocene-Holocene fluvial deposits of the Tiber River in Rome (Italy): lithofacies, geometries, stacking pattern and chronology

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INTRODUCTION

The Tiber is the second largest river in Italy having a catchment extended about 17,000 km^2. It began to develop since the Late Pliocene-Early Pleistocene times (Mancini and Cavinato, 2005, with references) and runs along the western flank of the Apennines crossing several extensional tectono-sedimentary basins of Neogene-Quaternary age. The lower reach of the Tiber system is comprised in the Roman Basin where, since the latest Early Pleistocene (approximately 1.0 Ma), formed a complex stack of multiple incised valleys (Milli, 1997; Milli et al., 2008; 2013) which includes mixed bedrock-alluvial, coastal plain and shelf segments.

This system records the fluvial responses to the complex interplay among the Late Quaternary glacio-eustatic sea level fluctuations, the local volcanic activity of the Sabatini Mts and Albani Hills complexes, the regional uplift of the Apennines, the ultimate extensional tectonic activity, and the sediment input from upper catchment areas.

In the Roman Basin fluvial incised valleys are recognised since MIS 26, and constitute the elements of several fourth-order depositional sequences with a duration variable from 30 to 120 kyrs, stacked to form a composite third-order sequence named Ponte Galeria Sequence (Milli, 1997; Milli et al., 2008; 2013). Among the recognized incised valleys the most representative and best preserved is that one formed in response to the last sea level fall occurring after the last highstand phase correlated to MIS 5. The infilling deposits of this incised valley are part of a 4th-order depositional sequence named "PG9 sequence or Tiber Depositional Sequence, TDS" (Milli 1997; Milli et al., 2013, with references therein), which extends in the subsurface for at least 60 km from inland to sea. This sequence corresponds to the "Tiber River Synthem" of the official Geological Map of Italy at scale 1:50.000, CARG Project (Funiciello and Giordano, 2008).

The Tiber Depositional Sequence has been particularly studied in the sector below the present Tiber delta plain where the passage from wave-dominated estuary to wave-dominated delta has been restricted in detail by Milli et al. (2013).

Conversely, a detailed stratigraphic-sedimentologic reconstruction of the fluvial valley infill and of the buried morphology of PG9 is lacking in the inland sector, whereas several studies on the geological-geotechnical and hydrogeological features of the terrains constituting this sequence have been proposed in recent years (Bozzano et al., 2000; Campolunghi et al., 2007; Raspa et al., 2008; Di Salvo et al., 2012).

The aim of this short paper is to present the new stratigraphic and sedimentological date on the Upper Pleistocene-Holocene deposits constituting the filling of Tiber incised valley in the subsurface of Rome. The goal is to better define the depositional architecture of the valley infill and the stratigraphic relationships between fluvial and estuarine deposits within a high-frequency depositional sequence like that TDS.

METHODS

The investigated area corresponds to the whole Tiber alluvial plain crossing the urban area of Rome within the G.R.A. (Grande Raccordo Anulare) highway ring (Fig. 1). This area is about 25 km long and 2.5 km wide, and shows a decreasing altitude between 20 and 8 m above sea level from inland to the inner coastal plain. The alluvial plain is deeply confined by hilly uplands formed by Plio-Pleistocene continental and marine deposits and by volcanic successions. The present plain corresponds to the top of the PG9 incised valley whose filling is about 60-70 m thick. The Tiber River is about 150-200 m wide, crosses longitudinally its plain and is a meandering style river, with 1,57 sinuosity index (Mancini et al., 2009).

The upper portion of the study area is covered with an up to 10-15 m thick layer of anthropogenic deposits that formed during the last three millennia of intense human modification, at least in the centre of Rome. Nevertheless, the ancient Tiber channel belt as well the two symmetrically peripheral floodbasin belts bordering the river can be inferred from the analysis of historical maps (Funiciello, 1995) and from the present day morphology of the non-urbanized northern and southern areas.

The stratigraphic architecture of the PG9 valley infill has been reconstructed by the examination of about 900 boreholes, collected by public administration and private companies and stored in the CNR-IGAG database (Fig. 1). The stratigraphy of these boreholes was utilized to construct several correlation panels crossing the valley with the aim of: 1) defining the shape of the valley and the sequence boundary at the valley base; 2) distinguishing the main stratigraphic-sedimentologic elements (channel bodies, floodplain deposits, levee-crevasse deposits, organic rich and peat layers, etc.) composing the valley infill; 3) recognizing internal surfaces of sequence stratigraphic significance, useful to correlate the inland fluvial deposits with the coastal plain estuarine deposits of the PG9 sequence.

Two new boreholes (named ATS Tiber 1 and ATS Tiber 2) were drilled recently in the centre of Rome (Figs. 1 and 2) in the frame of the ATS Tiber Project (Joint Venture among CNR-IGAG, Sapienza Università di Roma, ANAS, Geoplanning, E&G, and Sondedile S.r.l.). The boreholes cross almost entirely the Tiber Sequence reaching the gravel deposits occurring at the base of the unit. ATS Tiber 1 was drilled at the Prati neigh-borhood and mostly consists of floodplain deposits, while ATS Tiber 2, drilled close to Castel Sant'Angelo on the western bank of the river, consists of channel deposits.

A detailed facies analysis was performed on the two cores and several (peat fragments and terrestrial gastropods) were collected at different depths for

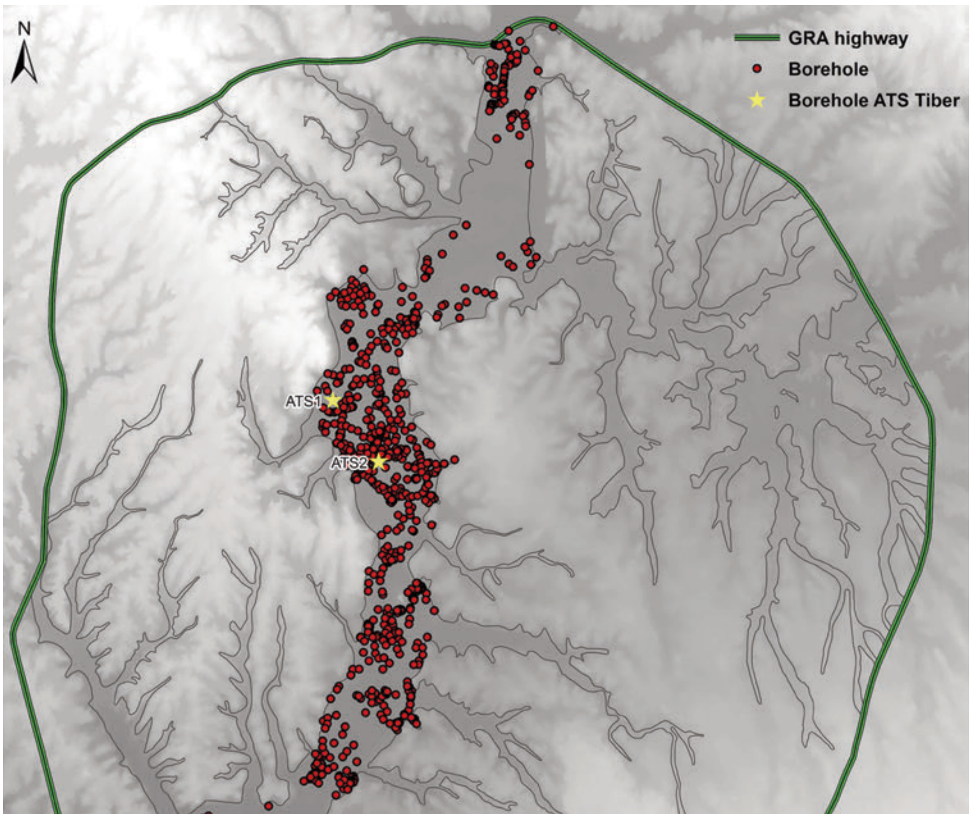

Fig. 1 - Location of the study area and of boreholes stored in the CNR-IGAG database. ATS Tiber 1 and 2 are the drilled boreholes whose logs are shown in figure 2.

radiocarbon dating (Fig. 2). This provided reliable stratigraphic and sedimentologic constraints for interpreting the correlation between the previously selected boreholes, and for estimating rates of aggradation within the valley infill. Two transversal correlation panels, crossing ATS 1 and ATS 2, show the reconstructed stratigraphic architecture of the incised valley (Fig. 3).

STRATIGRAPHIC ARCHITECTURE

The incised valley infill is up to 60-70 m thick and is deeply entrenched into the Plio-Pleistocene bedrock. The width/thickness (W/T) ratio (Gibling, 2006) of the incised valley is variable from approximately 25 to 40.

The sequence boundary at the valley base (SB in figure 3) is U-shaped and is easily recognizable in the subsurface because it abruptly separates the basal valley infill, commonly constituted by gravels, from the underlying Plio-Pleistocene bedrock. When the infill is constituted by fine sediments these are softer and less dense than the underlying strongly over-consolidated and very dense sediments of bedrock, which equally permits to identify the sequence boundary with ease.

Within the valley infill some important surfaces are recognized, which have successfully been correlated with the sequence boundary (*SB*), the first transgressive surface (*ts*) and the maximum flooding surface (*mfs*) recognised in the Tiber estuarine deposits occurring in the coastal plain paleovalley (Milli et al., 2013). Based on these surfaces the valley infill is vertically partitioned into three portions: 1) a lower portion about 5-10 m thick, bounded at the base by the *SB* and at the top by the *ts* which comprises the deposits attributed to the late lowstand systems tract of PG9; 2) an intermediate portion, up to 40 m thick, which is bounded at the base and at the top by the *ts* and *mfs* respectively, and that corresponds to the transgressive systems tract of PG9; 3) an upper portion, about 20 m thick, bounded by the *mfs* at the base and by the ground surface at the top that corresponds to the highstand systems tract of PG9 (Fig. 3).

The late lowstand systems tract deposits are composed by an almost continuous tabular body of gravels, 6-8 m thick, that vertically grades into a narrower sheet of pebbles and sands, forming a complex of amalgamated bars and bedload sheets, which have been attributed to a braided channel belt. Minor floodplain fine deposits, composed by consistent and well consolidated grey clay and silt, are present and are restricted in the more peripheral parts of the basal infill, where they laterally confine to the pebbly-sandy body. Pebbles are composed of limestone, with subordinate chert, arenites and rarer volcano-clastic material (pumice and tuff); the sands are rich in quartz, feldspar, muscovite and ferromagnesian minerals.

The transgressive and highstand systems tracts are vertically characterized by persistent fluvial deposits showing: i) a channel-belt complex, composed of sands and silty sands arranged into a series of vertically stacked active channel bodies (Gibling, 2006) or channel-belt sandstones (Blum et al., 2013), with minor silty-sandy levee deposits; ii) thick floodplain fine deposits rich in organic matter, with several peat layers and with local crevasse splay and abandoned channel deposits.

The single channel bodies show: 1) an erosive basal surface, the channel scour (*cs* in figure 3), well detectable where channel bodies overlay floodplain fine deposits; 2) pervasive small and medium-scale cross strata forming bars and bedload sheets filling active channels; 3) a fining upward trend, with medium-coarse sands and rarely pebbles at the base passing upward to fine silty sands and sometimes mud plugs.

All these characters are recurrent and almost regularly repeated in the channel belt complex. This have allowed to identify at least 7-8 vertically stacked channel bodies in the transgressive and highstand systems tracts. The width of a single channel body ranges from 400 to 800 m ca, while the thickness is in the order of 6-10 m, with a 40-130 W/T ratio. The reconstructed channel-belt at various depth shows in plain view (Fig. 4) patterns of sinuosity that may suggest the location of lateral accreting side bars and the downstream accretion from tributaries.

Grey-bluish clay and mud very rich in organic matter and reotrophic peat layers with sandy silt overbank and crevasse splay sediments constitute the floodplain deposits, generally poorly consistent and consolidated that form, together with coeval channel bodies, the main architectural elements of the PG9 transgressive systems tract. The TST channel bodies are in general narrower and without evident levee facies respect to the channel developed in the highstand systems tract.

The presence of peat layers allow us to date the TST deposits in the time interval spanning from 12 kyr to 7 kyr BP. For this interval estimated floodplain aggradational rates, without considering peat and clay compaction, are in the order of 7 mm/yr in the lower TST, while 15 mm/yr are reached in the upper TST just below the *mfs*.

Consistent and overconsolidated, grey to greenish and pale brown, floodplain clay, mud and silt constitute most of the PG9 highstand systems tract (Fig. 3). In these deposits peat layers are rare, while dry paleosols, rich in carbonate concretions, Fe/Mn oxides nodules, terrestrial gastropods and root traces, are frequently found. Channel bodies tend to be wider and are commonly associated with silty-sandy levee facies and minor inactive channels, interpreted as meander cut-off or chute channels filled with fine sediments. Floodplain aggradational rate is in the order of 2.8-3 mm/yr, while the channel-belt complex shows a higher degree of lateral amalgamation of active channel and levee deposits than the underlying TST deposits.

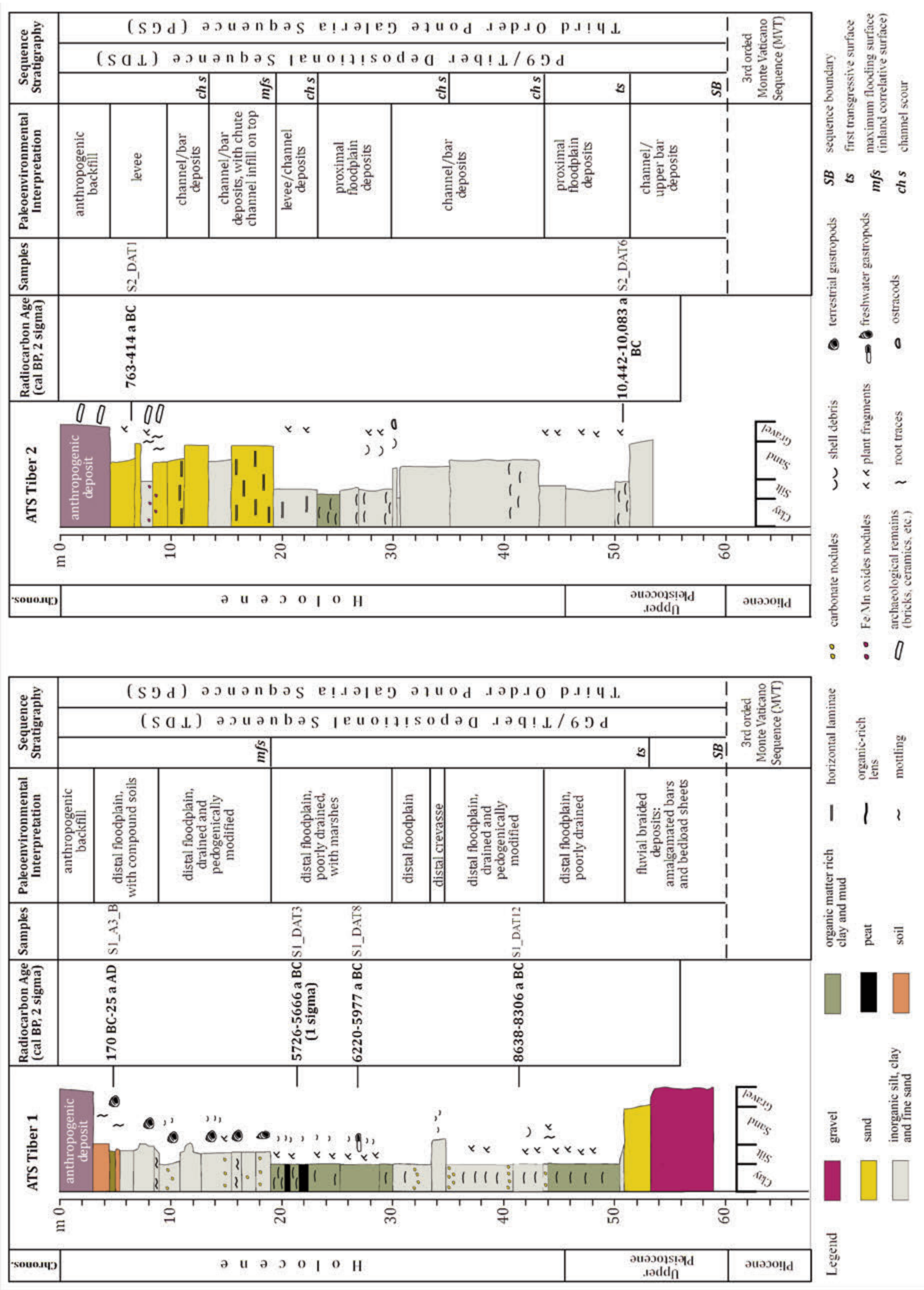

Fig. 2 - Borehole logs of ATS Tiber 1 and 2, with environmental interpretation and depth of dated samples (peat fragments and mollusks). ATS Tiber 1 and 2 are representative of the floodplain and channel-belt respectively.

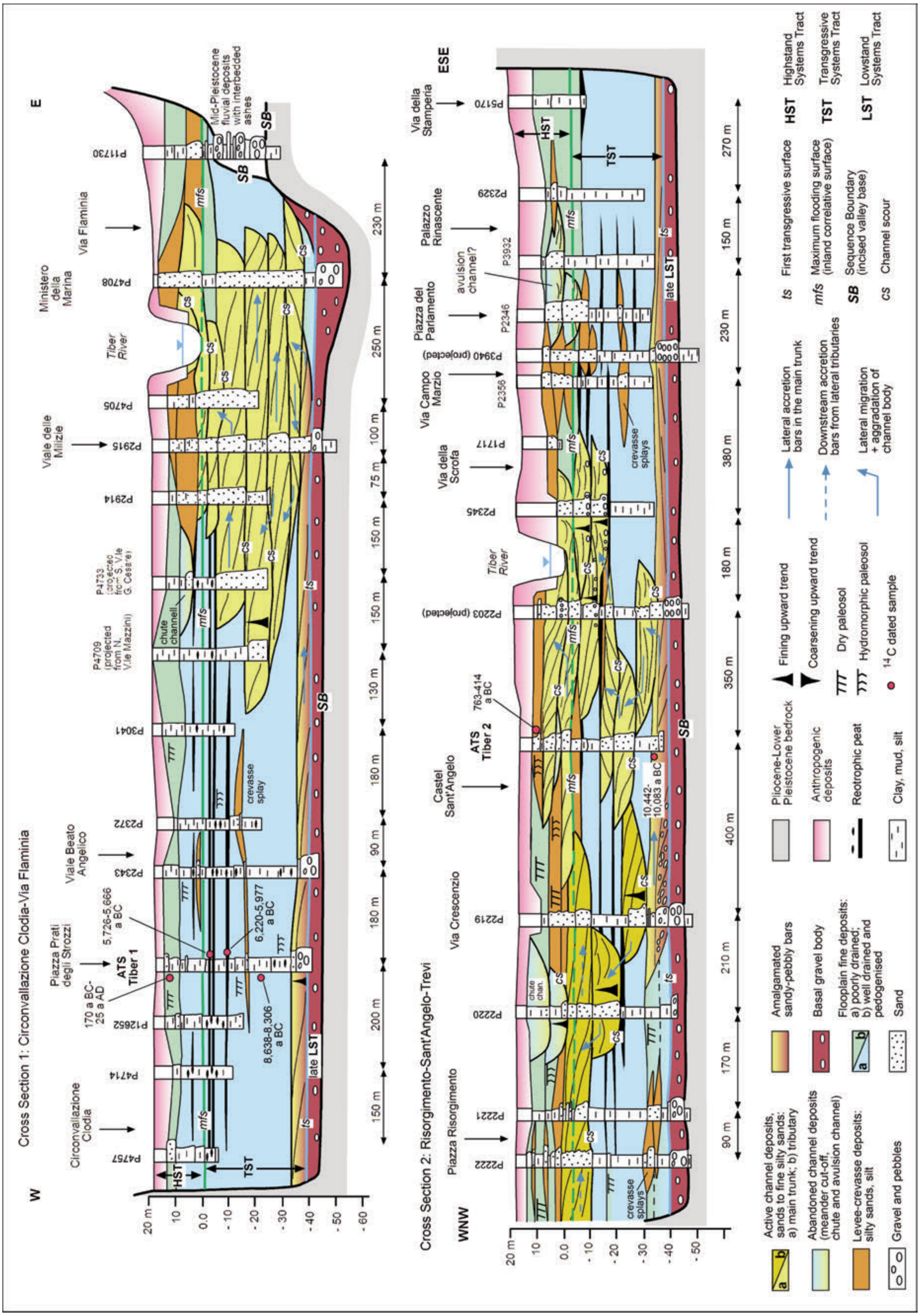

Fig. 3 - Transversal cross sections showing the stratigraphic architecture of the Tiber valley fill in the centre of Rome.

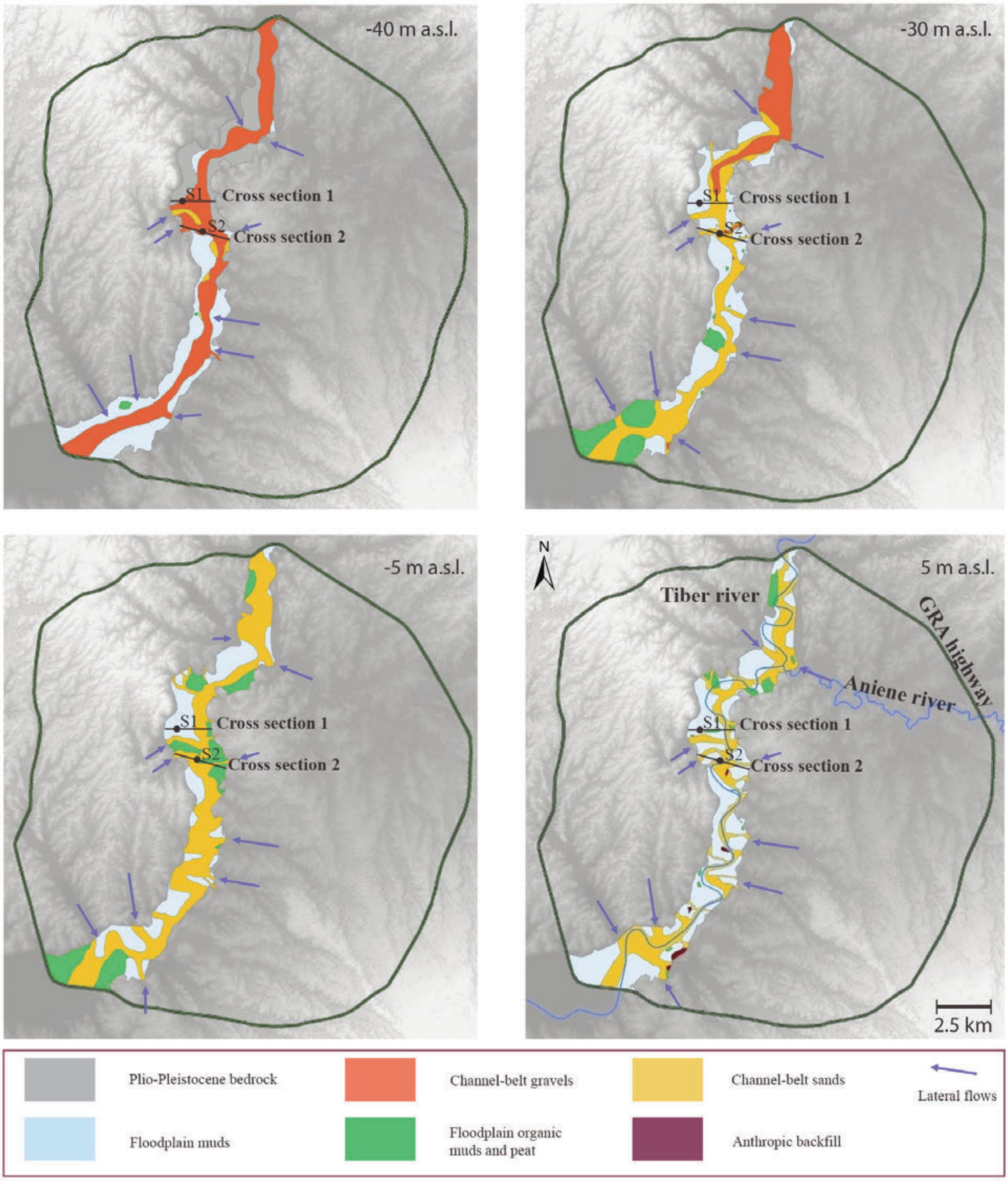

Fig. 4 - Paleogeographic reconstructions of the Tiber Valley, with well distinguished channel-belts and floodplain areas, at different depths: -40 m a.s.l., late lowstand systems tract; -30 m, early transgressive systems tract; -5 m, late transgressive systems tract; 5 m a.s.l., early highstand systems tract (partly modified after Mancini et al., 2009).

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