

## THE PO DI ADRIA, FRATTESINA AND THE PO DELTA BETWEEN THE MIDDLE-RECENT BRONZE AGE AND THE EARLY IRON AGE.

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**PAROLE CHIAVE:** Età del Bronzo, paleolaveo, accrescimento verticale e orizzontale, bocca di foce del Po, cordone litorale.

**KEYWORDS:** Bronze Age, paleochannel, aggradation, progradation, Po river mouth/outlet, littoral ridge.

### RIASSUNTO

L'areale basso veronese-alto polesano nella seconda parte del Periodo Sub-Boreale fu soggetto, insieme a larga parte della pianura padana, a condizioni climatiche di tipo continentale, marcate da oscillazioni più umide (Oscillazione di Löbber), contrassegnate infine da punte terminali di tipo sub-arido. Contemporaneamente si fece sempre più consistente l'impatto antropico derivato da un'estesa diffusione degli insediamenti nella bassa pianura padana. All'interazione di questi fattori vengono addebitati i primi significativi cambiamenti documentati nel regime fluviale della cintura del Po, un'arteria padana già presente in area dalla prima metà del III millennio a.C., con un percorso settentrionale, denominata da chi scrive Po di Adria 1.

Le evidenze di questi primi mutamenti paleoidrografici sono la formazione di canali di rotta, di ventagli alluvionali e le divagazioni di vari tratti di aste fluviali, ora meno stabili che nelle fasi precedenti (Fase post-Canar I e pre-Canova: BA-BM, XVII-XVI sec. a.C.).

Questi primi cambiamenti nei regimi fluviali furono seguiti da una fase di relativa stabilità, che coincise con la fase di massima espansione insediativa dei siti terramaricoli nella pianura padana centro-orientale tra l'età del Bronzo Media e Recente (BM-BR). Durante questa fase si assiste, soprattutto nell'areale compreso fra la Bassa Pianura Veronese e l'alto-medio Polesine, alla fioritura di una rete di siti connessi con il *chiefdom* di Fondo Paviani.

Agli scorcio di questa fase si colgono le prime avvisaglie di un deterioramento del territorio pianiziaro densamente insediato, accentuato dall'ipersfruttamento dei suoli e dal successivo collasso del sistema insediativo terramaricolo. Tra la fine del ciclo terramaricolo e l'inizio della successiva parabola insediativa di Frattesina (tra BR2 e BF1) sono documentate alcune ulteriori trasformazioni paleoidrografiche e paleoambientali i cui effetti dall'*hinterland* basso-veronese/alto polesano si estesero ad interessare le fasce più orientali del sistema deltizio-costiero padano del tempo.

Si coglie ora (tra BR2 e BF1) la transizione da un ambiente con canali molto sinuosi, anastomizzati, circondati da bacini in cui predominano sedimentazioni fluvio-palustri, ad uno a canali sub-rettilinei con larghi meandri sabbiosi, a cui si associa la costruzione delle prime e più evidenti fasce di argini naturali: questi nuovi pattern morfologici segnano la transizione dal Po di Adria 1 al Po di Adria 1/2. Queste evidenti trasformazioni paleoidrografiche sono causate in larga parte dalla confluenza di una nuova diramazione padana, il Po di Poggio Rusco-Dragoncello-Sermide, esito di una grande diversione delle portate padane a partire dal nodo idraulico di Brescello-Guastalla, nel Po di Adria 1, a dare una più efficiente configurazione al corso padano, denominato per l'appunto Po di Adria 1/2. Al contempo, si osserva un incremento nelle progradazioni dei corpi costieri (cordoni di dune e fasce di spiaggia) favorite dalla confluenza degli apporti congiunti del f. Adige e del Po di Adria.

Queste nuove dinamiche, a causa del taglio e dell'obliterazione di una serie di meandri molto sinuosi, ereditati dal periodo precedente (meandri di Ceneselli e Campestrin), influirono sulla disorganizzazione e insieme parteciparono ad una rapida obliterazione del preesistente reticolo di canalizzazioni antropiche aventi recapito nel f. Tartaro, e al contempo posero in serie difficoltà i collegamenti fra il sito centrale di Fondo Paviani e il delta del Po, una connessione sino ad allora basata su una equilibrata confluenza del f. Tartaro nel Po di Adria.

Dopo una fase di forte riduzione e di abbandono praticamente generalizzato delle sedi terramaricole (BR2 avanzato), seguì, a partire dal BF1, una fase di rapido recupero e di riassetto nel regime della "nuova" diramazione padana, il Po di Adria 1/2, favorito dall'instaurarsi di condizioni climatiche mediamente più secche delle precedenti. Questa più stabile situazione determinò le condizioni ottimali per la fondazione del sito di Frattesina, posto all'apice del sistema deltizio originato dagli apporti della principale diramazione padana del

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tempo, ora disgiunta dalla connessione con l'Adige, in seguito all'intasamento per sovralluvionamento della diramazione di Saline-Cona. Queste nuove condizioni di recupero di un assetto fluviale stabile "in equilibrio pressoché gradato" per il Po di Adria, determinato dalla confluenza del Po di Poggio Rusco-Dragoncello-Sermide nell'antico Po di Adria 1, favorirono la rapida ascesa del polo trasformativo e di scambio di Frattesina, ruolo che perdurò quasi ininterrottamente per i tre secoli del BF.

Agli inizi dell'età del Ferro (IFe1) si verificarono mutamenti paleoambientali ancora più traumatici ed estesi dei precedenti, determinati dall'instaurarsi di una fase climatica di tipo oceanico-freddo accompagnato da punte di aridità (oscillazione di Göschenen I). Questo cambiamento climatico ebbe riflessi nell'incremento del tasso di aggradazione dei corsi fluviali, che ora evidenziano accentuati fenomeni di sopraelevazione degli alvei, cui seguono reiterate sequenze di tracimazioni, esondazioni e rotte fluviali. A questi disastrosi processi paleoidrografici si associano vistose alterazioni nelle morfologie delle linee di costa, causate da profonde erosioni associate a disordini di origine meteo-marina. Tutti questi processi condurranno rapidamente al sovralluvionamento dell'intera asta fluviale del Po di Adria 2, che subirà, di lì a breve, una completa avulsione delle sue portate nei pressi di Castelmassa, culminata nella Rotta di Sermide, l'episodio formativo della nuova diramazione settentrionale del Po di Ferrara (Po di Spina).

## ABSTRACT

The Southern Verona Lowlands /High-Polesine territories, in the second part of the Sub-Boreal period were subject together with a large part of the Po Plain to continental climatic conditions, interrupted by damp oscillations (Löbber oscillation), finally marked by sub-arid terminal peaks. At the same time, the anthropic impact derived from a widespread dissemination of settlements in the lower Po Valley became increasingly consistent. The interaction of these factors is debited from the first significant changes in the fluvial regime of the Po River, a principal padanian artery already present in the area from the first half of the III millennium B.C., travelled by a northern branch that I have called Po di Adria 1.

The evidences of these first hydrographic changes are the formation of new flood-channels, of crevasse-splays and the diversions of various stretches of river courses, now less stable than in the preceding phases (post-Canar I and Pre-Canova phase: EBA-MBA: XVII-XVI century B.C.). These first changes were followed by a phase of relative stability, which coincides with a stage (MBA-RBA) of maximum settlement expansion of the Terramare sites in the central-eastern Po Plain, during which we assist, especially in the range between the South Verona plain and the Upper-Middle Polesine deltaic region, a flowering of a network of sites connected to the main *chiefdom site* of Fondo Paviani.

To the end of this phase, the first evidences of a deterioration of the densely settled Po Plain territories, accentuated by the overexploitation of the soils and by the subsequent collapse of the Terramare settlement system, are seized. Between the end of the Terramare cycle and the beginning of the successive settlement cycle of the Frattesina site (between RBA2 and FBA1) some further paleohydrographic and paleoenvironmental transformations are documented, the effects of which from the hinterland Low Verona/High Polesine plains extended to affect the most eastern belts of the deltaic-coastal system. It now captures (between RBA2 and FBA1) the transition from an environment with very sinuous canals, anastomized, surrounded by basins dominated by peats-marsh sedimentation, to sub-rectilinear canals with wide sandy meanders, to which is associated the construction of first and most evident stripes of natural banks: these new morpho-fluvial patterns mark the transition from the Po of Adria 1 to the Po of Adria 1/2. These evident paleohydrographic transformations are caused in large part by the confluence of a new Po branch – The Po di Poggio Rusco-Dragoncello-Sermide, a result of a great diversion of the Po river flow from the hydraulic node of Brescello-Guastalla, in the Po of Adria 1. This new asset give a more efficient configuration to the Po course, named Po of Adria 1/2. At the same time, an increase is observed in the progradations of the coastal bodies (dunes and beach ridges) favoured by the confluence of the discharge contributions of Adige River in the Po di Adria River.

These new dynamics, due to the cutting and obliteration of a series of very sinuous meanders inherited from the previous period (Ceneselli and Campestrin meanders), influenced the disorganization and participated in a rapid obliteration of pre-existing anthropic canals network having delivery in the F. Tartaro, at the same time placing serious difficulties to the previous connections between the central site of Fondo Paviani and the Po delta, now connected through the Po di Adria branch alone.

After a phase of strong reduction and generalized abandonment of the Terramare sites (advanced RBA2), followed, starting from the FBA1, a phase of rapid recovery and resettlement in the regime of the "new" Po branch, the Po of Adria 1/2, favoured by the establishment of new average climatic conditions, more dry than the previous ones. This more stable situation determined the optimal conditions for the Frattesina site foundation, located at the apex of the delta system originated from the contributions of the main Po branch of the time, now disjointed from the connection with the Adige river, in following the clogging for overflow of the Saline-Cona branch. These new conditions, for the recovery of a stable river structure "in almost-balanced equilibrium" for the Po of Adria,

determined by the confluence of the Po di Poggio Rusco-Dragoncello-Sermide in the ancient Po of Adria 1, favoured the rapid rise of the transformation and exchange pole of Frattesina, a role that lasted almost continuously for the three centuries of FBA.

At the beginning of the Iron Age (EIA1: IX-VIII century B.C.) there were even more traumatic and extensive paleoenvironmental changes of the previous ones, determined by the establishment of a climatic phase of oceanic-cold type, with dryness peaks (Göschonen I fluctuation). This climate change reflected in the increase in the aggradation level of river courses, which now show accentuated phenomena of superelevation of the riverbeds, followed by repeated successions of floodings and river breaches. To these disastrous paleohydrographical processes, there are associated evident alterations in the coastal lines morphology, caused by deep erosions associated with disturbances of marine-weather origin. All these processes will quickly lead to the overflow of the entire river tract of Po di Adria 2, which is shortly to undergo a complete avulsion of its flow near Castelmassa, culminated in the Sermide breach-flood, the formative episode of new branch of the Po di Ferrara (Po di Spina).

## INTRODUCTION<sup>2</sup>

Over the past few decades, a series of geoarchaeological surveys have been carried out in the more and more extensive sectors of the Southern Verona Lowlands (SVL) and the High-Middle and Lower Polesine (H-M and LP), in conjunction with archaeological research projects led by the Institute of Archaeological Sciences of the University of Padua. The two main ones (AMPBV Project and F. PAVIANI Project<sup>3</sup>; Fig. 1) were aimed at the study of the sites and their landscapes in the surrounding areas (devoted principally to agriculture and livestock) of settlement related to the *terramare* cultural phases (BERNABÒ BREA, CARDARELLI, CREMASCHI 1997) of the Middle-Recent Bronze Age. A very last look was then addressed to the “new sites” of the Final Bronze Age of the lower Po plain and upper delta plain areas (window in Fig. 1b).

In the Middle and Lower Polesine area (M-LPA), the regional *Soprintendenza per i Beni Archeologici del Veneto* and the *Museo dei Grandi Fiumi / CPPSAE* of Rovigo, led further research works that aim to gain a consistent amount of new knowledge and to develop significant advances in the understanding of the relationship between human settlements and territories for some areas of significant cultural value (see also BALISTA 2009a, 2009b, 2013 and PIOVAN, MOZZI, STEFANI 2010). The results of these recent archaeological investigations carried out on the Frattesina settlement of Fratta Polesine and then extended to its hinterland (“Progetto Frattesina” 2013-2016: DE GUIO *et alii* 2015; BALDO, BALISTA, BELLINTANI 2018; DE GUIO 2002), has highlighted the problem of this new central place site dislocation (dated to the advanced phase of RBA and to FBA). It is now proposed the new location from the SVL-HMP area towards the new FBA sites located in the M-L Polesine area was determined by the greater proximity to the ancient delta apex (Balista in BALDO, BALISTA, BELLINTANI 2018) (Fig. 2).

Under these pushes, the compartments of these investigations dedicated to the eminently geoarchaeological topics has changed. At first, the geo-sedimentological and geo-pedological researches on the immediate hinterland of the Bronze Age great sites were commonly led (BALISTA 2009, 2013; NICOSIA 2005, 2006; NICOSIA *et alii* 2011). More recently, the research evolved into the mapping and analysis of the most salient paleoriver traces and deposits, whose chrono-stratigraphic correlations could be established with some of the main archaeological sites previously documented in the area.

The remote sensing identification (BETTO 2013; BALISTA 2017; BURIGANA, MAGNINI 2017) of numerous traces of paleofluvial systems connected with the diversion of ancient meandering channels in the Po valley pertinent to the Po river belts, among which those referable to the Po di Adria play a very important role (VEGGIANI 1972, 1974; PERETTO 1986; ARENOSO CALIPPO, BELLINTANI 1994; PERETTO 1999; PERETTO, BEDETTI 2013), has been supported by a series of petrographic analysis of the deposits of the main paleochannels outcropping in the area (BALISTA 2007, 2013) (Fig. 3). The identification of these river branches, which flow around the south-western peripheral sections of the territories of the *terramare* enclave of the SVP (BALISTA, DE GUIO 1997), paved the way to a broader research perspective (Fig. 4). This focused on disentangling the possible interactions between paleoenvironmental changes and settlement duration, that are critically influenced by distinct phases of quiescence and/or greater activity of the ancient sections of the rivers tracts involved (Fig. 5). These paleo-hydrographic processes often gave rise to paroxysmal episodes of over-flooding of the riverbeds and flooding of the nearby banks and floodplain bands, which were then abandoned, due to the partial or total avulsion of the watercourses in correspondence of more or less long tracts of the fluvial belts related to inherent abandonment of the archaeological sites.

The study of the environmental factors that have influenced the demographic and socio-economic patterns of these areas, needs deeper knowledge of the paleo-environmental situations that could have influenced the new settlement choices. These choices were related to a new exploitation of the territory in terms of resources, lastly

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<sup>2</sup> Sincere thanks to my dear friends Flavia Amato and Marco Bruni that spared no efforts to make available my first rough translation of an essay that was for several reasons very complicated.

<sup>3</sup> Projects led by Prof. A. De Guio and Prof. G. Leonardi and M. Cupitò of the Faculty of Archaeological Sciences University of Padua, now Department of Cultural Heritage: Archeology and History of Art, Cinema and Music, University of Padua, Italy.

preferring the strategic locations more suitable for the exchanges, as those of the delta-coastal area of the ancient Po river connected to the trans-Mediterranean network area.



Fig. 1a-b. Geographical location of the investigated lowland plain and delta-coastal territories referred to the ancient delta of the Po di Adria. From the "Alto Medio Polesine-Bassa Veronese Project" and "Fondo Paviani Project" (Castello del Tartaro - CdT and Fondo Paviani - Fp), to the "Frattesina Project" (Frt) and the "Amolara di Adria" site (Amo).





Fig. 2. The ancient Po delta between the Bronze Age and the Iron Age was composed of two main river branches systems: a northern one built by the Po di Adria and a southern one centered on the Po dei Barchessoni/Po di Copparo. The occurrence of the Sermide Flood (in the VIII-VII cent. B.C.) marked the complete avulsion of the flows from the Po di Adria 2 towards Ferrara, originating the Po di Spina (preminent in the Iron Age).



Fig. 3. The ancient course of the Po di Adria, from Castelmassa to the sea (in light blue), reconstructed through microrelief (DTM) analyzed in correspondence of the Bronze Age Po river traces. Highlighted also the two branches of Saline-Cona to the north-east and Adria to the east (metric scale = 20 Km, vertical microrelief scale: from -5 to + 25 m asl) (sample points for petrographic analysis).



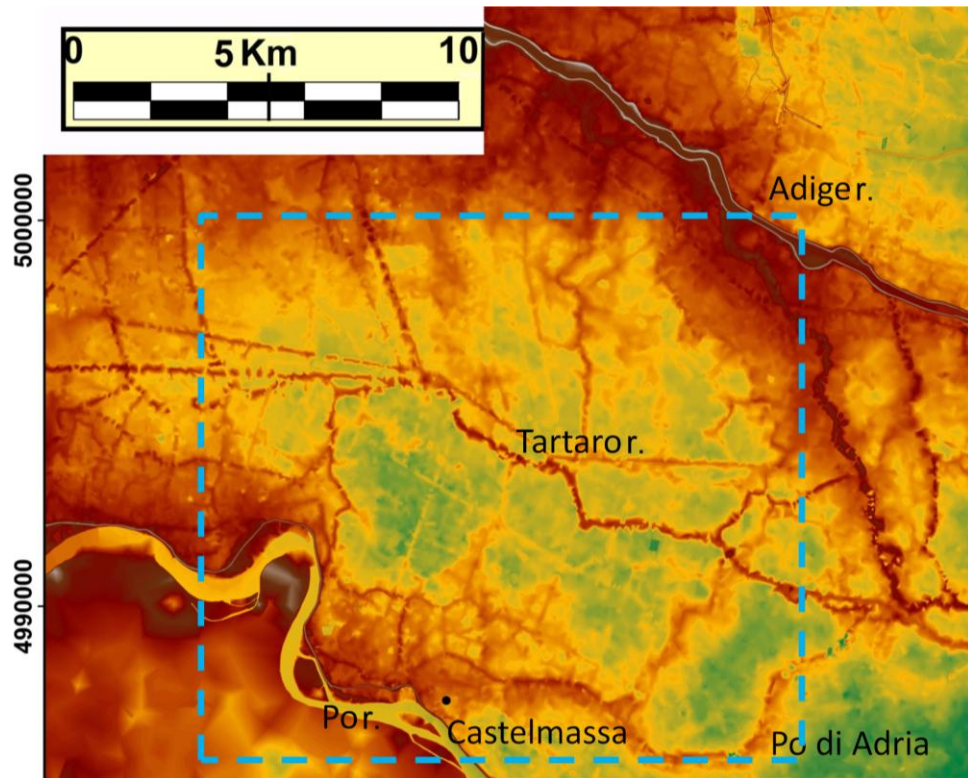


Fig. 4. During the recent stages of the Sub-Boreal chronozone, starting from the hydrographic node of Castelmassa, it is evident that the winding of Po di Adria appears to have interfered with the paleohydrographic situation on the southern border between the SVL (the area controlled by the polity of Fondo Paviani, Castello del Tartaro and Fabbrica dei Soci) and HMP (High-Middle Polesine).



Fig. 5. A sector of the extreme Southern Verona Lowland (SVL) seen from north-west. In the foreground the ring-shaped embankment of CdT, in the center the reclamation channels of the Tartaro river and in the background, towards south-east, just before Castelmassa, the meanders of the Po river.

The link between these two situations of the Verona and Polesine sectors, not so far but distinguished from each other, could be identified with the ancient Po di Adria route (Fig. 6). This river belt has determined, with its palaeohydrological and paleo-morphological asset, not only the habitability and land-use of the nearby areas but, above all, it constituted a ready "waterway" for contacts and traffic to/from the sea (BELLINTANI, SARACINO 2015). Therefore, I collected the most complete and up-to-date documentation concerning the main hydrographic and geomorphological transformations of the ancient fluvial belts of the central-eastern Po Valley and the watercourses that once flowed in its neighboring areas. At the same time, a comparison between morpho-fluvial patterns (rivers with anabranching, anastomosed, meandering, straight path, etc.), channels geomorphology (watercourses with an incised bed, a course at the same topographic level of the plain, perched, etc.) and evolutionary ancient status/stages (active, quiescent, abandoned waterway, etc.: BALISTA 2003) was indispensable knowledge, not only for the Po di Adria but also for the coeval paleochannels (of the Mantua district in the north-west and of the Emilia district in the south-west).

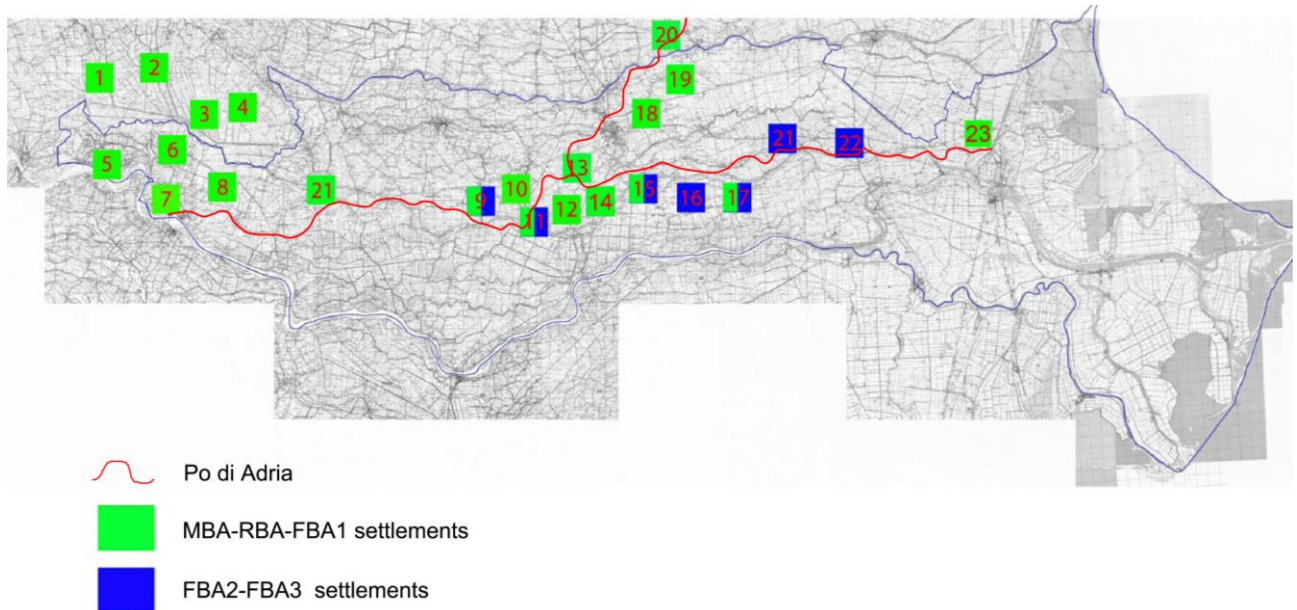


Fig. 6. The Po di Adria course and the major settlements of the MBA-FBA1 (in green) and the FBA2-EIA1 (in blue) in the SVL and HMP areas, on an IGM topographical map (1 : 25,000); surveyed sites : 1. Castello del Tartaro; 2. Fondo Paviani; 3. Fabbrica dei Soci; 4. Stanghelletti; 5. Mariconda di Melara; 6. Canar di San Pietro Polesine; 7. Castelnovo Bariano; 8. Marola; 9. Trecenta; 10. Frattesina; 11. Gognano; 12. Villamarzana - Frassinelle; 13. Arquà Polesine; 14. Grignano Polesine; 15. Balone; 16. Pontecchio Polesine; 17. San Cassiano; 18. Larda-Gavello; 19. Sarzano; 20. Saline-San Martino di Venezze; 21. San Giusto-Anguillara Veneta; 22. Cicese; 23. Adria (from "Progetto AMPBV-Tele-Frattesina 2013" DE GUIO *et alii* 2009, by A. De Guio).

The results of these analyses required to establish a correlation series based, as far as possible, on the synchrony of the activities in the sections neighboring to that of the Po di Adria, based on absolute dates ( $^{14}\text{C}$ ), and/or relative dates (archaeological and geological), linked with the main "phases" of settlement presences (sites) in the territories. The surveys addressed to these issues have brought out a series of new questions related to the geographical, paleo-hydrographic and settlement scenarios prevalent in these areas during the period considered (from the EBA-MBA-RBA to FBA1-FBA2 and to FBA-EIA1: Fig. 6). For this purpose, the chronology proposed in the literature for the main local archaeological sites investigated (Fig. 7) was used to formulate new hypotheses on the settlement geographical and chronological distribution patterns and therefore of co-occurrence (presence) and/or rarefaction (absence) of settlements in relation to coeval paleo-environmental situations. The period under consideration span between the end range of the Bronze Age and the beginning of the Iron Age, a period of outstanding growth in the economic-cultural aspects of human settlements in the Po Delta area (BALISTA *et alii* 1998, ATZORI *et alii* 2005) and south-western Venetian coast (CUPITÒ *et alii* 2015b, BELLINTANI, SARACINO 2015). These questions required a new data collection, especially for the Holocene coastal deposits area of the South-Western Veneto and North-Eastern Emilia-Romagna coastal areas. For this purpose, the knowledge of the fluvio-deltaic and coastal depositional setting of the modern Venezia, Rovigo and Ferrara provinces related to the Po di Adria has been updated<sup>4</sup>. In the end, I focus on the critical evaluation of the main phases of fluvial/alluvial activity in the territories nearby the paths of the Po di Adria. Those phases were compared to those of geomorphic stability,



expressed by quiescence or abandonment of sections of the hydrographic networks involved, or, to a larger scale, with those identified in correspondence with branches of the Po river delta and / or Adige river branches.

	Bagolan, Leonardi 2000	Cardarelli 2010 Cupitò, Leonardi 2015	Pare 2008	De Marinis 2014
BR1	1300 - 1200	1350/1300 - 1200		
BR2	1200 - 1150	1200 - 1150		
BF1	1150 - 1100		1140/1100 - 1060 ca.	
BF2	1100 - 1000		1060 ca. - 1035/1010	1061 - 1048 1054 - 1037
BF3	1000 - 900		1035/1010 - 910 ca.	1010 - 955
IFe1	900 - 800		910 ca. - 850/830	910 - 876 878 - 850

		Frattesina		Fondo Zanotto Narde I	Narde II
		superficie	scavo		
		Bellintani 1992; 2000	Bietti Sestieri et al. 2015	Colonna 2006	Salzani, Colonna 2006
1200 - 1150 ca.	BR2	Fase 1	Livelli non scavati	Non presente	Fase 1
1150 - 1100/1060 ca.	BF1			?	
1100/1060 - 1000 ca.	BF2	Fase 2	Fase 2	Fase I	Fase 2
1000 - 910 ca.	BF3	Fase 3	Fase 3	Fase II	
910 - 830 ca.	IFe1		Livelli distrutti ( Fase 4? )	Fase III	

Fig.7. The adopted archaeological chronology: from the Recent Bronze Age to the Early Iron Age of northern Italy-central and eastern sectors (from BALDO, BALISTA, BELLINTANI 2018, elab. P. Bellintani).

## 1. THE PALEO-HYDROGRAPHIC SITUATION IN THE AREA BETWEEN THE LOWER MANTOVA-MODENA PLAIN/HIGH FERRARA PLAIN (SOUTH OF PO DI ADRIA) AND SVL AND H-MP PLAINS (NORTH OF PO DI ADRIA) DURING THE EBA-MBA AND THE MBA-RBA

During the second part of Holocene, the general development of fluvial belts in the territories crossed by the Po di Adria, in the sectors between the Mantova-Cremona border (to the west-north/east) and that of Mantova-Reggio E. (to the west-south/west) followed the guidelines of deposition/accumulation from southwest to northeast. Those movements were controlled mainly by the dynamics of the tectonic structures in the subsoil, under the thrusts of the Apennine foreland in progressive overlap on the flaps of monoclinical South-alpine formations and from the presence of major subsident areas interposed between them. Therefore, to follow in an orderly manner these lines of formation of new territories towards the river course of the ancient Po di Adria, I will follow the formative developments of the main river bands starting from the Emilia sector. Then I will move in the range of the Oltrepò Mantovano to finally arrive to an area more properly related to the riparian strips of the Po di Adria, between the plain basins of the Po and Adige rivers, south-east to the Southern Verona Lowlands (SVL) and in the central-western sector of the Polesine plain (HMP) (Fig. 8a)<sup>5</sup>.

<sup>5</sup> These areas, over the last few years, have been interested by numerous and in-depth researches of eminently geological arguments, by the institutes of Geosciences of the Universities of Venice, Padua, Ferrara and Bologna, as well as the CNR and various institutes of coastal and marine research (CNR, Ispra, etc.), aimed at the carrying out of projects such as, for example, the edition of the new Italian geological sheets 1:50,000 Ispra-Regione Emilia-Romagna and Regione Veneto.



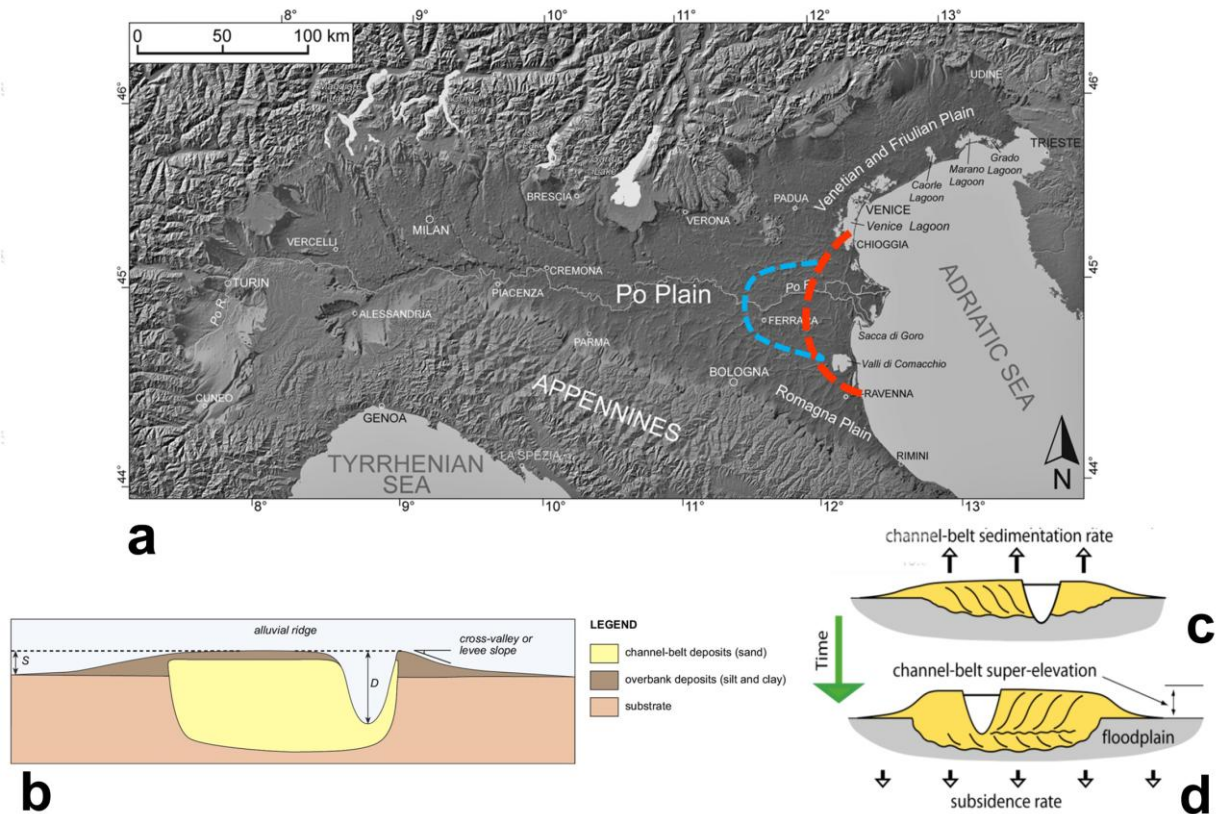


Fig. 8. The geographic and geomorphological physiography of the eastern Po Valley area (a). Changes from incised channels (central-western) to perched channels (central-eastern), mostly subject to avulsions (modified from FONTANA 2012). At the beginning of the Bronze Age, the ancient coastline was set back by approx. 30–40 km than the current one (from blue to red line). b-d). Draft of river evolution on lower flood-plain: from incised (b), to weakly suspended (c), to super-elevated river-bed (d) (from GOUW 2007).

### 1.1. The situation during the Early and Middle Bronze Age (EBA-MBA) and the Middle-Recent Bronze Age (MBA-RBA) in the lower Po plain, Emilia district.

In the areas of central-eastern Po Plain, the main paleo-hydrographic traces for the investigated period coincide very often with diversion segments of more extensive hydrographic systems, which mainly consist of large river belts, with long-term activities. It should be noted that a relatively frequent phenomenon in the northern (Po di Adria) and the southern sectors (Po di Ferrara /Po di Spina sectors<sup>6</sup>) corresponds (and certainly corresponded) to the occurrence of processes of "reoccupation" (by confluence) and/or "avulsion" (by diversion or bifurcation), of various segments of pre-existing river channels and therefore of increasing and/or reduction (from temporary to definitive) of the flow-sediment volumes in transit on the sections of river tract involved. These processes, together with the widespread presence of "super-elevated riverbeds" (ridges)<sup>7</sup>, gave quite frequently the trigger to phases of avulsions (both partial and total) of the flows of the paleochannels located inside of the individual river belts domains. Consequently, the beginning of gradual abandonment phases of fluvial courses occurred, along flow directions placed outside the first, in the most depressed areas (Fig. 8b).

In these central Po plain areas, the preferential routes of diversion of fluvial avulsion are and were controlled themselves by the situations of the local geological substrates<sup>8</sup>. These activations are mainly caused by tectonic dislocations related to reactivation of the thrusts of the Po plain-Adriatic foreland belts, which very often end with earthquakes characterized by truly superficial epicenters<sup>9</sup>. In this area the ancient routes along the belts of the old course of the Po river were situated not only beyond that between Serravalle and Ostiglia, but mostly upstream from it, between Brescello-Guastalla and Suzzara-Pegognaga: they are clearly marked by the presence of important

<sup>6</sup> We propose this term in place of the most abused one of the "Po di Spina". In fact, this last river Po track, corresponded to the secondary branch in the deltaic area of the Po di Ferrara, which forked immediately downstream of this location in parallel with the other branch of the Po di Copparo.

<sup>7</sup> See the formation of perched riverbanks on the local ancient ground level in Fig. 8.

<sup>8</sup> The local geological substrates are subjected to slow processes of subsidence that occur very often to a limited depth between the major arches of buried tectonic folds ("Pieghie Emiliane and Ferraresi") covered locally by thin Late Quaternary/Holocene layers.

<sup>9</sup> See the most recent Emilian earthquakes of 2012.

tectonic lineaments buried at short depth (CASTELLARIN 1986; AMOROSI *et alii* 2008b; CASTALDINI *et alii* in press; STEFANI *et alii* 2018) (Fig. 9).

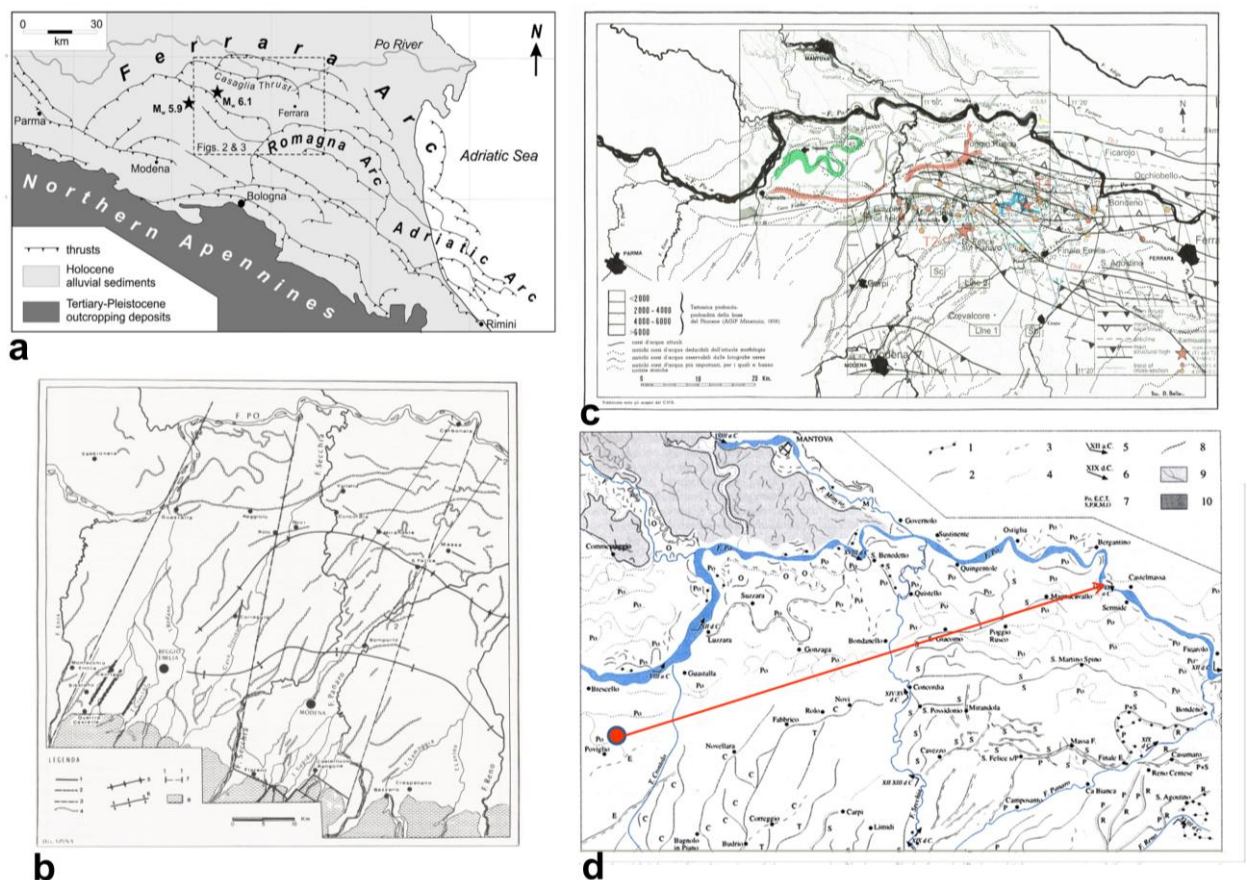


Fig. 9. Tectonics and paleo-hydrographies in the central area of the Po plain. The course of the river Po is largely controlled by the tectonic structure of the local geological substrates, buried at shallow depths. Are evident the morphogenetic relationships established between the Po di Adria paths and the diversion-corridors for the Po river that take place between S. Rosa di Poviglio and Castelmassa during the Sub-Boreal period. a) tectonic thrusts (modificato da PIERI, GROPPI 1981); b) tectonic faults (da Memoria Università di Modena); c) the Po di Poggio Rusco-Dragoncello-Sermide path (in red) (da PELLEGRINI 1969); d) the main trajectory for the Po river diversions during Bronze Age (da CASTIGLIONI, PELLEGRINI, 2001, pp. 97).

About the focused period, the research I carried out in both the Modena and Ferrara sectors (between Mirandola and Pilastris near the actual Po river), (BALISTA 2003, 2005, 2006, 2007) highlighted the results of tectonic phenomena, connected to reactivation phases of the thrust of the folds/faults of the Romagna-Ferrara Arcs, as for example, those evidenced by the anomalies that have been preserved in the figures of the abandoned meanders of the Po dei Barchessoni ridge (BALISTA 2007), or the diversions of the route of the major local tributaries (Secchia and Panaro Rivers: ASTORI *et alii* 2002; BURRATO *et alii* 2012).

It should also be noted that in the central Po plain area, the waterways meet numerous torrential river courses that are often characterized by flows overloaded by mobilized sediments following the occurrence of climatic oscillations and/or derived from areas impacted by new colonization waves in previously wooded areas, or finally resulted from the abandonment of previously densely settled territories (such as in the case of abandoned areas following the end of the settlement cycle of the *terramare* culture, cfr. BALISTA 2009b). These territories, which extended from the hilly sides of the Apennine relief to the morainic ones of the Pre-Alpine relief (DE MARINIS 2006), embracing the entire plain section of the central-eastern Po valley, as is well known, in the advanced Bronze Age (MBA-RBA) were disseminated by agrarian-settlement infrastructures (canalizations, ditches, embankments and earthworks, fields, territorial networks of agricultural canals, etc.), as well as almost completely deforested and reduced to pastures areas (CREMASCHI 2017)(Figs. 9-10).



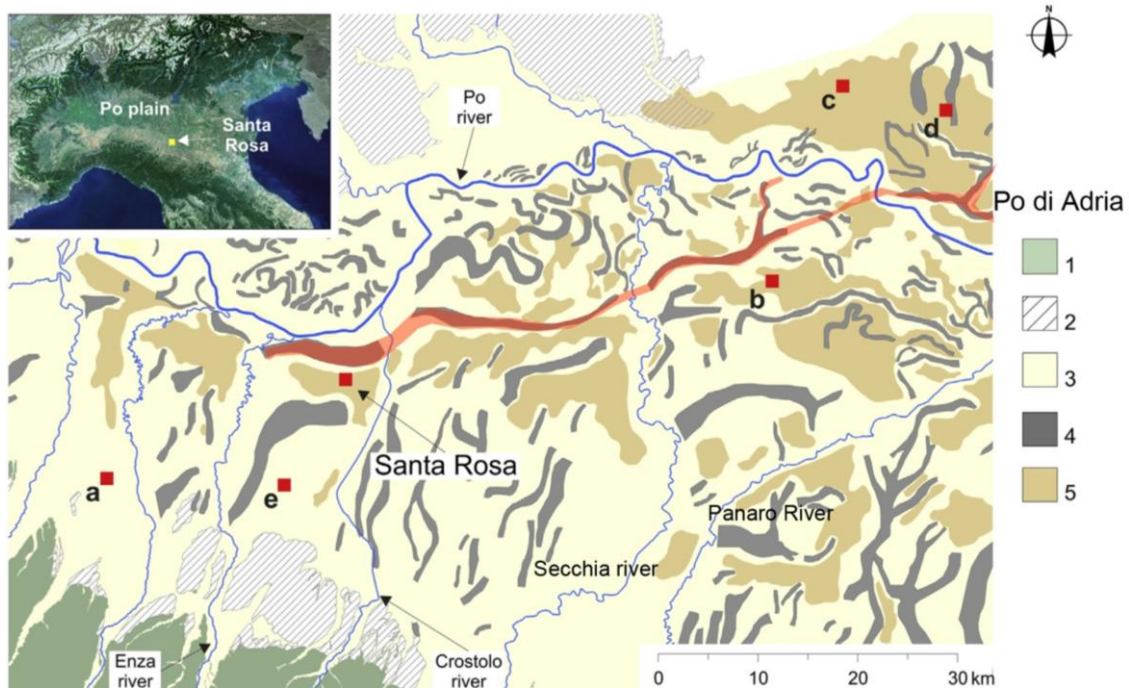


Fig. 10. The Po di Adria 1/2 course could be interpreted as the result of a reoccupation, by confluence, of the Po di Adria 1 by a Po branch called Po di Poggio Rusco-Dragoncello-Sermide, coming from south-west (in red). This watercourse would have entered the aforementioned corridor due to tectonic thrusts and following the abandonment of the southern Po dei Barchessoni paleochannel path. This interpretative proposal would allow us to establish significant correlations between the paleo-hydrographic evolution of the two areas, Emilia and upper-middle-Polesine, which are characterized by the spread of the sites of the same *terramare* culture. Legend: 1=Pre-Quaternary deposits; 2=Pre-Holocene terraces; 3=Holocene alluvial plain; 4=paleo-channels; 5=poorly drained lowlands (adapted from MELE *et alii* 2013).

Regarding these "northern-emilian" sectors, (but the same phenomena involved the contiguous SVL/H-MP sectors) a first forerunner phase of major palaeohydrographic changes, and therefore contributing of significant paleoenvironmental transformations, may have occurred during the second part of the Sub-Boreal chronozone (Figures 6a-6b). Specifically, it should be linked to the time frame corresponding to the archaeological phase between the EBA and the MBA (CREMASCHI *et alii* 2016), a period that includes the wet climatic oscillations of Lössben dated between 1625 and 1550 cal BC (NICOLUSSI *et alii* 2001; HAAS *et alii* 1998, MAYEWSKY *et alii* 2004), preceded and concluded by more punctual sub-arid episodes (Sub-Boreal warming 1 and 2 in ZUBAKOV, BORZENKOVA 1990) (Figs. 11a-b and 12a-b).

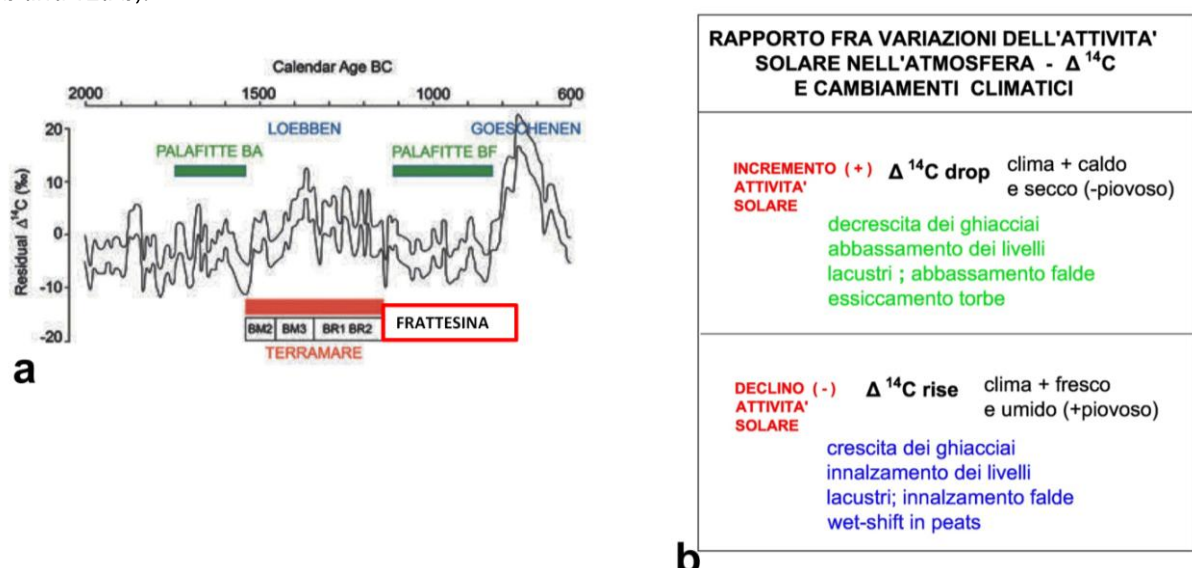


Fig. 11. a) General paleoclimatic situation of the eastern Po plain within the second part of the Holocene, from the late Sub-Boreal to Sub-Boreal/Sub-Atlantic transition. During the two wet and cold fluctuations of Lössben and Göschenen 1 there were large diversions of the Po river that in part influenced the paleo-hydrographic evolution of the area (modified from CREMASCHI *et alii* 2017). b) Chart of the outcomes of the two extreme paleoclimatic situations shown in a) (modified from BLAAUW *et alii* 2004).

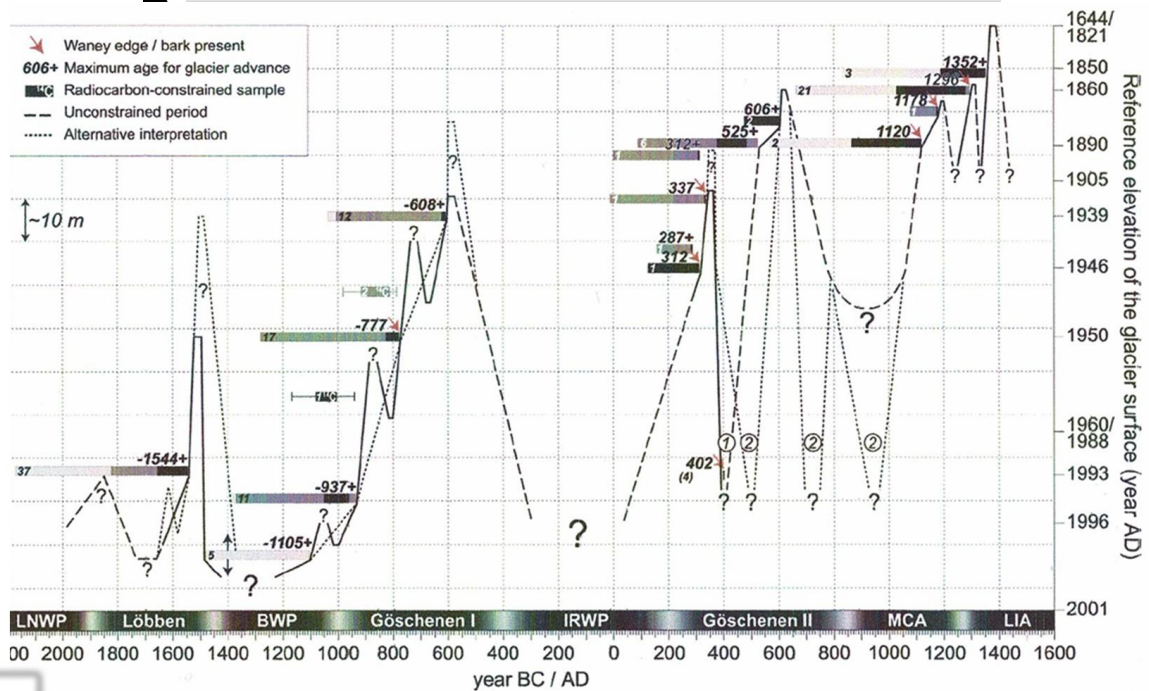
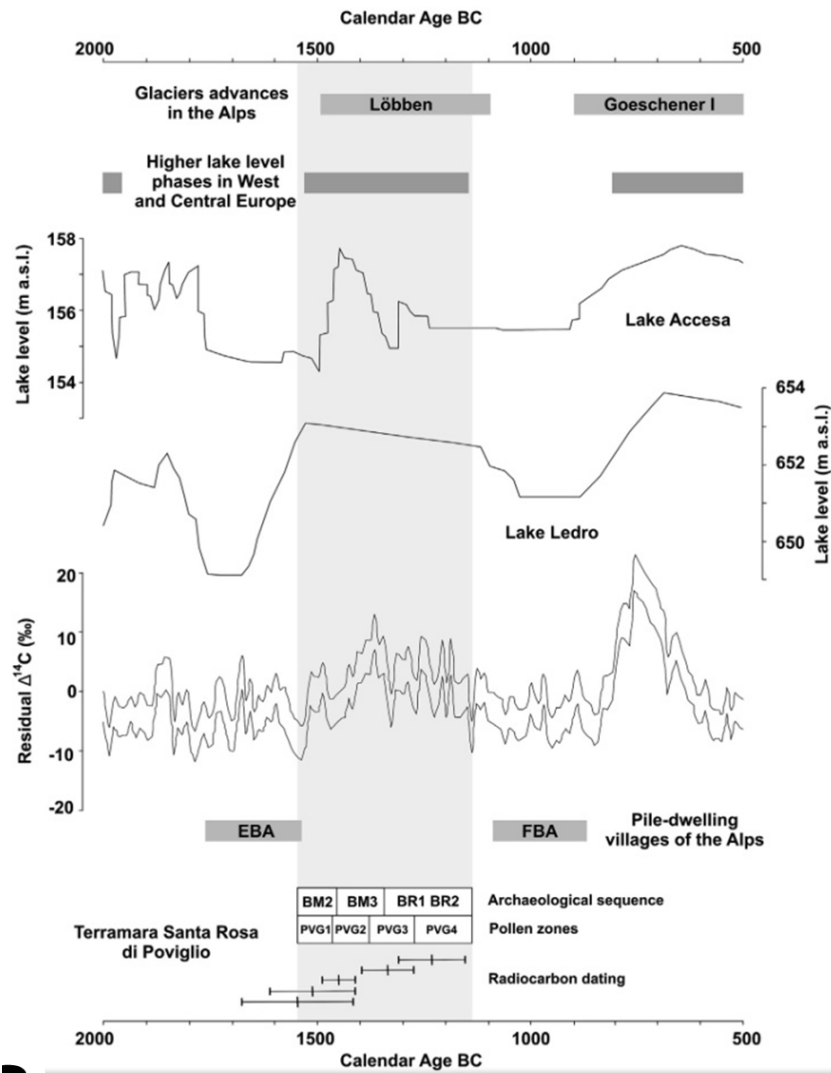


Fig. 12. a) According to CREMASCHI *et alii* 2016 the Löbben phase (glacial advance = higher levels of the lakes) extends the wet-cold effects to the entire MBA and RBA, followed by a dry period that includes the entire FBA, up to Sub-Boreal / Sub-Atlantic transition. b) Some other authors (LE ROI *et alii* 2015) limit the Löbben phase effects between 1600 and 1500 BC cal.



The processes that are recorded in these territories between the end of the EBA and the beginnings of the MBA as well as involving the recurrent phenomena of breaching of natural banks, formation of flood-channels and crevasse splays, are characterized by the deposition of extensive flood deposits connected to the formation of ephemeral long flood-channels, which expand from the Reggio Emilia province area up to the southern Mantova province one. Thereby the characteristic morphological elements named “dossi”<sup>10</sup> are formed: Dosso di Cividale di Mirandola - Dosso Palazzo - Dossi Pavignane and La Tesa di Mirandola in the south; Dosso della Falconiera - Stoppiaro-Pilastrì to the north of the Po dei Barchessoni<sup>11</sup> (Fig. 13). These “raised paleochannels” preserve on their tops numerous *terramare* sites, settled between the MBA-RBA (CARDARELLI 2003). These paleohydrographic phenomena would therefore be mainly due to the recurrence of overloaded flood episodes, as result of highly variable climatic situations widespread in this period (and perhaps largely boosted by tectonic components).

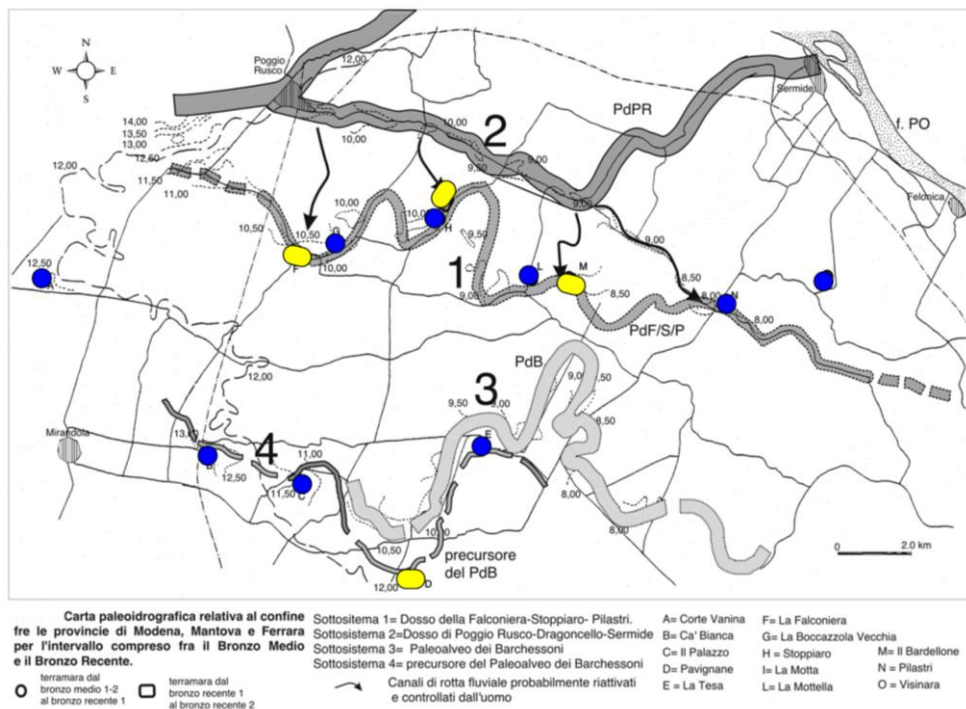


Fig. 13. *Terramare* settlements in the border area between the provinces of Mantova, Modena and Ferrara: sites of MBA-RBA1 in blue; sites of RBA1-RBA2 in yellow. The Po dei Barchessoni (3) and the Po di Poggio Rusco-Dragoncello-Sermide (2), active between the RBA (in light grey) and the FBA1 (in dark grey). Note the location of the *terramare* sites (MBA) on the ridges of the minor hydrographic network (secondary ridges: 1 and 4 correspond to formative avulsion flood-channels of the “Po dei Barchessoni” system (ridge 3).

## 1.2. The situation in the “Oltrepò Mantovano” area.

The analysis of the paleo-hydrographic system formed by the two nearby Po river paths that have been recently identified: **Po of Adria 1** in the north, and Po di Poggio Rusco-Dragoncello-Sermide<sup>12</sup> in the south (BALISTA 2017) has revealed the direct genetic derivation of the southern branch from the most ancient north-western one. It was a result of a regional avulsion in the section between Casalmaggiore and Guastalla. Then we observed the reoccupation by confluence of the southern into the northern one, as highlighted from the presence of the great Castelmassa crevasse splay (see below)<sup>13</sup>. Although some authors (RAVAZZI *et alii* 2013) point out that the confluence occurred in the surroundings of Ostiglia, nevertheless this proposal does not invalidate the contemporary activity of the two branches of the Po rivers (Fig. 14). This synchrony would in fact be validated by the position and stratigraphic situation found at the Mariconda di Melara site. Noteworthy in this site, located near the modern channel of Po river between Ostiglia and Castelmassa, thick alluvial deposits that separates the upper stratigraphic complex (dated to the FBA1-2) from the lower one (dated to RBA2-FBA1-2) (DALLA LONGA 2015; FASANI 1966; SALZANI 1973) were documented. This thick overflow interval could be therefore related with a renewed phase of flood-channel activity, probably connected with the confluence between the two rivers above.

<sup>10</sup> The word “dossi” could be translated as ridges.

<sup>11</sup> The paleo-hydrographic landscape illustrated in Fig. 13, a stratigraphic window recorded in extreme detail through surveys dedicated to the main sites of the *terramare* culture outcropping in the area of the lower Modena plain (see BALISTA 2003), reproduces in a vivid way the local fluvial geomorphology in the Po plain area at that time.

<sup>12</sup> A secondary Po branch activated after that of the Po dei Barchessoni.

<sup>13</sup> According to a model of “aggradative avulsion” well known in literature (see MOHRIGH *et alii* 2000; fig. 7 in BALISTA 2007). See, however, the exhaustive discussion on the subject in STOUTHAMER 2001.

The most accurate and recent series of observations conducted not only remotely, but also on the field (BALISTA 2017), highlighted the presence of a clear geographical separation between the two fluvial belts of each route, and especially brought out a distal origin of the paleochannel referable to the Po di Poggio Rusco-Dragoncello-Sermide, with derivation from south-south/west. This distal origin exceeds the limits of the current Po river belt, as already reported in the dedicated maps and recently published (CASTALDINI *et alii* in press) (Fig. 14).

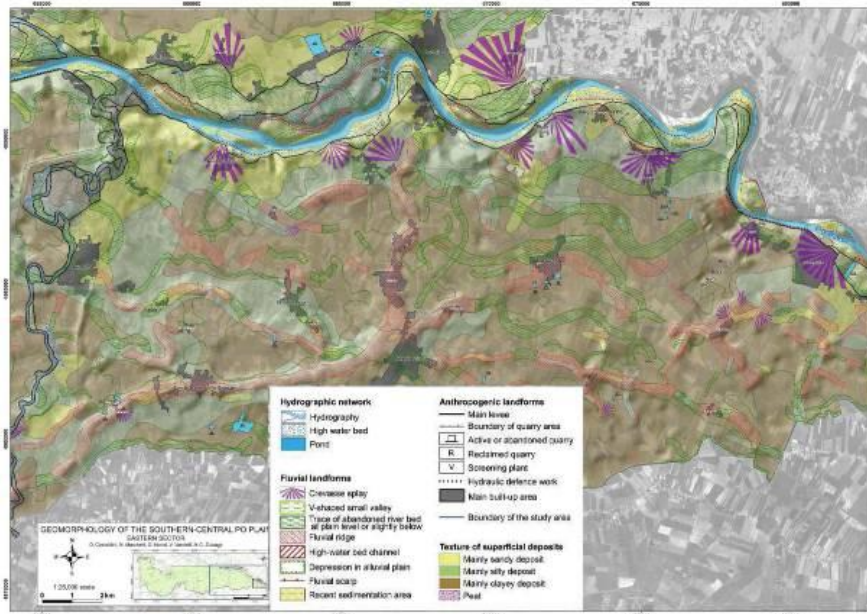


Fig. 14. The updated restitution of the prehistoric Po river paleohydrographic network, identified through new field surveys and remote sensing carried out in the Oltrepò Mantovano-Destra Secchia sector, highlights the microrelief of the ridges corresponding to the route of the Po di Poggio Rusco-Dragoncello-Sermide. This path is located near the Poggio Rusco town, where one course branches off towards the ancient Po di Adria near Ostiglia, while the second sprawls, slightly south-west of Sermide, suggesting a confluence in the ancient Po di Adria at Castelmassa (modified by CASTALDINI in press).

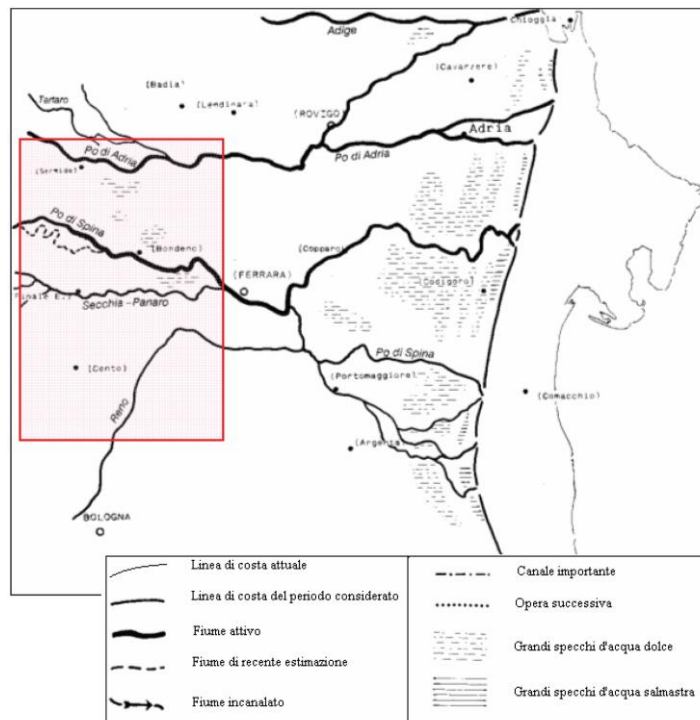


Fig. 15. Schematic map of the main palaeohydrographies recognized in the high-Ferrara plain area/Mantova-Modena border, during the advanced Bronze Age. The Po di Spina, which received the drains of the Secchia-Panaro system after Bondeno, flowed to the north of the Po dei Barchessoni and, towards the delta, it mainly fed the branch of the Po di Copparo. In this map it is not reported the path of the Po di Poggio Rusco-Dragoncello-Sermide, which course was completed in the advanced RBA and FBA, while the formation of the Po di Spina occurred only after the complete avulsion of Po di Adria 2 (modified from BONDESAN 2001, 1990).

According to Castaldini (1989, 1996) in the 2nd millennium B.C. the Po was subdivided in the area between Casalmaggiore and Guastalla in a main branch (Po di Adria) and in one or more secondary branches sub-parallel to it (Po di Ferrara: Po di Copparo and Po di Spina). Traces of these routes are the paleochannels identified in Viadana, Sabbioneta (BALISTA 2005) and Commessaggio areas (Mantova-Cremona border areas: BALISTA 1995b) for the Po di Adria and in Poviglio (Reggio Emilia province), Concordia sulla Secchia and San Martino in Spino (Modena province) for the Po di Ferrara. This relatively "remote" origin for the more recent route of the Po di Adria has been ascribed to the effects of a series of climatic-morphogenetic changes, which occurred in some sections of the Po riverbed, located between the Reggio E. and the Mantova areas at the Recent Bronze Age. However, in literature, more emphasis is given to the subsequent phase of reorganization of local paleohydrographic network that occurred at the beginning of the Iron Age (VIII-VII century B.C.), coincident with the results of the Brescello-Guastalla and Sermide floods, and the subsequent establishment of the Po di Spina course (the one I quoted as Po di Spina 2 (see footnote 16 and fig. 8a in BALISTA 2013).

A previous phase (some centuries earlier), well attested in correspondence of the settlements of the Final Bronze Age in the Upper Middle Polesine (see the location of the Frattesina and Villamarzana sites, on the same tract of the new Po di Adria 1/2) (BALISTA 2013, footnote 16) is usually neglected in the framework of studies covering of the western area.

Recent stratigraphic corings, carried out near the southern embankments of the Pilastris *terramara* in Ferrara province (MBA1-RBA1: DESANTIS 1991, DESANTIS, STEFFÉ 1995), have allowed to document some episodes of reactivation of the local river branch<sup>14</sup>, referable to the route of the Po di Poggio Rusco-Dragoncello-Sermide river<sup>15</sup>, during the last phase of the MBA-RBA (Fig. 16). These processes were recorded thanks to a detailed stratigraphic analysis carried out in the sections of channeled river deposits that "abut" against the *terramara dike* on the west side of the embankment<sup>16</sup>. Some absolute dates, recently acquired (AMS-CS: sample <sup>14</sup>C\_19 = 1612-1450 BC (2 sigma) and sample <sup>14</sup>C\_18 = 1611-1448 BC (2 sigma)<sup>17</sup>, have outlined the presence of a fire that affected the timber posts features located at the top of the silty-sand embankment. They correspond to the remains of burned wood which were buried on the occasion of a new sediment accumulation due to the embankment rebuilding. This new deposit, in turn, preserves residual dispersions of pottery and bone on its ancient surface, as well as pits and postholes traces. Latest analysis would predate these structures, or at most would be synchronous to the last settlement phase, which would be related to layers of inhabitations occurred shortly before the last phase of reactivation of the river discharge. This major river over-flooding ended in a river branch diversion formative of a perched channel ridge named "Argine del Campo" which was settled only starting from Middle-Late Iron Age (see SARONIO 1987, 1988) (Fig. 16).

These more recent evidences (see also Bardellone site, FERRI 1989, BALISTA 2007 and BALISTA 2017) of paleo-hydrographic episodes recorded in correspondence of fluvial segments nearby-to south- from the course of the Po di Adria, have opened the possibility of supporting, with greater reliability, a phase of reoccupation of the High-Middle Polesine Po river tract due to a contribution-confluence from the Po di Poggio Rusco-Dragoncello-Sermide river (Fig. 21). These increases in the Po discharges would have caused variations in the river flows that triggered various chains of related processes, such as the meander-neck cut-offs of Ceneselli and Campestrin (*infra*), in addition to the episode formation of numerous crevasse channels and splays, as the one that prepared the platform for the settlement of the Frattesina site. These episodes should be related with the continuous flooding in the riverbed that led to the total avulsion of the flows of the Saline-Cona branch (which would seem to have occurred exactly during the paleo-hydrographic transformations just mentioned<sup>18</sup>.

The phenomena connected to the individuation of the Po di Poggio Rusco course and above all its confluence in the river belt of the ancient Po di Adria 1, are therefore the result of important paleo-hydrographic transformations occurred in correspondence with the previous Po river in unstable equilibrium and already previously subject to fluvial diversions directed to spread over the territory of Mirandola (see the paleochannels ridges to the south and to the north of the Po dei Barchessoni in BALISTA 2007). These refer to the section of the paleochannel ridge facing the modern town of Guastalla (see BALISTA 2007, fig.7 and Sheet 182 Guastalla - ISPRA 2009, online edition), where there is a large flood-channel that originated a stable branch of the Po river, known in literature as Po di Poggio Rusco-Dragoncello-Sermide (BALISTA 2007). Noteworthy, this paleochannel trace corresponds to the route of the Po di Ferrara (with its branch called Po di Spina 1), formed as a result of the northern dislocation of the Po dei Barchessoni flows (whose river belt, in a no longer active phase, hosts sites of FBA3-EIA1: see the site of Montirone,

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<sup>14</sup> Near which was raised the Terramara itself.

<sup>15</sup> The same one that fed the Pilastris Terramara moat.

<sup>16</sup> See "trench B", field report 2013-2014 by Balasso and Michelini, PETRA-Padova, unpublished.

<sup>17</sup> Personal communication by Prof. Massimo Vidale, Faculty of Archaeological Sciences University of Padua, that here I thank, together with all the members of the Excavation Project of the Pilastris Terramara.

<sup>18</sup> See the tract at the confluence of the Po di Adria in the Po di Poggio Rusco-Dragoncello-Sermide between Sermide and Castelmassa, marked from the archaeological discovery of di FBA site of Sermide (DE MARINIS 1999).



BELLINTANI 1994). This river path seems to reach the position of Poggio Rusco-Dragoncello-Sermide, as shown by the over-flooding of the moat and part of the site of Bardellone (MN) shortly after the RBA2-FBA1<sup>19</sup>. The wide plain strip, no longer crossed by the primitive river belt of Po di Barchessoni, was soon overflowed for the insertion of the flows of the Crostolo and of the Secchia rivers and, more eastwards, of the Panaro river (Fig. 17). These confluences gave origin, together with those of the Reno river, to the path of the Po di Ferrara of protohistoric age.

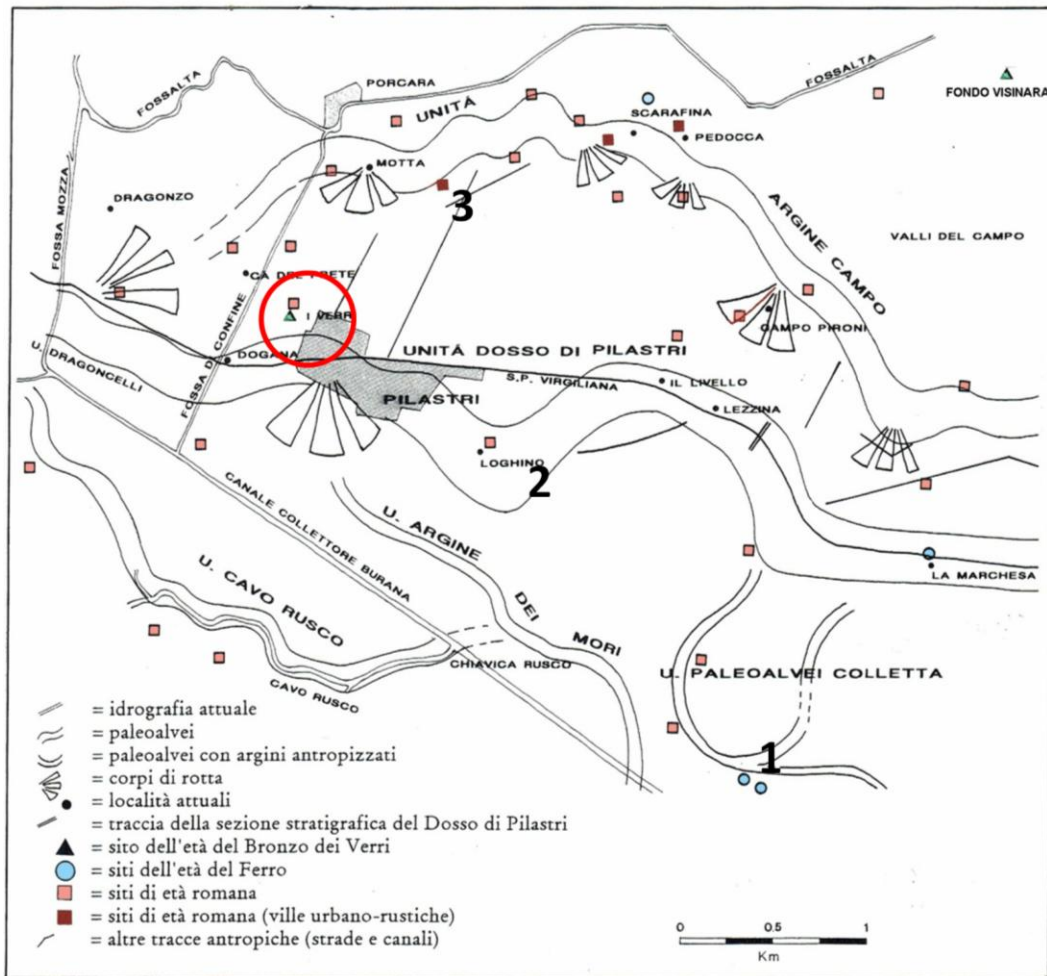


Fig. 16. The main river ridges' routes identified in the Pilastri *terramara* proximity: 1) ancient meandering paleochannels cut-off from 2) the main ridge of the Po di Poggio Rusco-Dragoncello Sermide that arose before the foundation of the Pilastri *terramara* and then was reactivated, shortly before its abandonment (early RBA?). The abandonment of the main ridge-drainage appears related to the opening of crevasse splay and flood channels to form 3) the Argine del Campo ridge on which Iron Age sites remains have been found (modified by FERRI, CORNACCHINI 1995 and by BALISTA 1995a).

Regarding this still partly unsolved issue, the most recent research led by the team of C. Ravazzi in the Oltrepò Mantovano area (RAVAZZI *et alii* 2011, 2013) does not seem to have increased the knowledge (indeed would tend to partly confuse it):

- firstly RAVAZZI *et alii* (2011) mention a diversion of the Po river in Guastalla that occurred in the Iron Age, which would have led to the abandonment of the Bondeno paleo-riverbed<sup>20</sup> (a Po course considered active for most part of the Bronze Age) and simultaneously caused the over-flooding of the area between Suzzara, Ostiglia and Mirandola. This same overflooding and the aforementioned diversion would have caused the damming of the Valle del Mincio, and the consequently origin of Bagnolo S. Vito (Mantova) paleolake<sup>21</sup>.

<sup>19</sup> Referring to the chronological range of the site materials (RBA2-FBA1: DE MARINIS 1987).

<sup>20</sup> In the map of Fig. 17 the track of the Bondeno river corresponds in this paper to the path ascribed to the Po di Poggio Rusco-Dragoncello-Sermide.

<sup>21</sup> A story about it: in RAVAZZI *et alii* (2013) it is said that at the base of the lacustrine series, on the littoral belt of the site, the phase of organic accumulation (which captures itself in cover of the previous river sequences), was formed in part during the "Late Bronze Age": (core FOR 6) <sup>14</sup>C BP: 3025 +/-35; 95% cal/BC, 1396-1192 BC. The data in the middle of the lacustrine basin (deeper) indicate that the lake transformation of the Mincio (river) Valley would have occurred at the beginning of the Middle Bronze Age: (core BAGN 1): <sup>14</sup>C BP: 3234 +/-45; 95% cal/BC, 1614-1425 BC, prevailing on the abandoned channel section of the Mincio River.



- secondly, in their new map (RAVAZZI *et alii* 2013, fig. 6a) they called the Bondeno route "sub-Apennine Po river"<sup>22</sup>. In this regard, in the text it is reiterated that "the main diversion of the axis of Po river towards north is commonly referred to the climatic deterioration of the 8th century BC"<sup>23</sup>. Therefore, it is assumed that the abandonment of the Bondeno channel segment, active during the Bronze Age, and the diversion of Po river in Guastalla (due to the migration of the Po di Adria to the north) were the main causes of the over-flooding of a wide strip of the plain between Suzzara, Ostiglia and Mirandola.

Ultimately, as alleged by the aforementioned authors, the new path of the "sub-Apennine" Po, reactivated in the VIII century B.C., have taken a sliding direction towards east-northeast and, beyond Poggio Rusco, have entered the riverbed of the Po di Adria 1 between Ostiglia and Sermide, to give rise to an extensive series of overflows of large tracts of the floodplain surrounding the Po di Adria. In this analysis there is no mention of any element that shows a possible connection between the Po river branches of the Oltrepò Mantovano and those long identified in the Polesine area, especially as regards the Po di Adria, which during the advanced FBA flowed nearby the important settlements of Frattesina and Villamarzana<sup>24</sup>. Particularly this statement, which is very significant, would constitute in our opinion an unchallengeable paleo-hydrographic situation that would predate the diversion of Po di Bondeno in the Po of Adria for several centuries. The situation I consider appropriate to the series of evidence collected in the field, and partly by the literature, has been summarized in Fig. 17 (modified from BALISTA 2017).

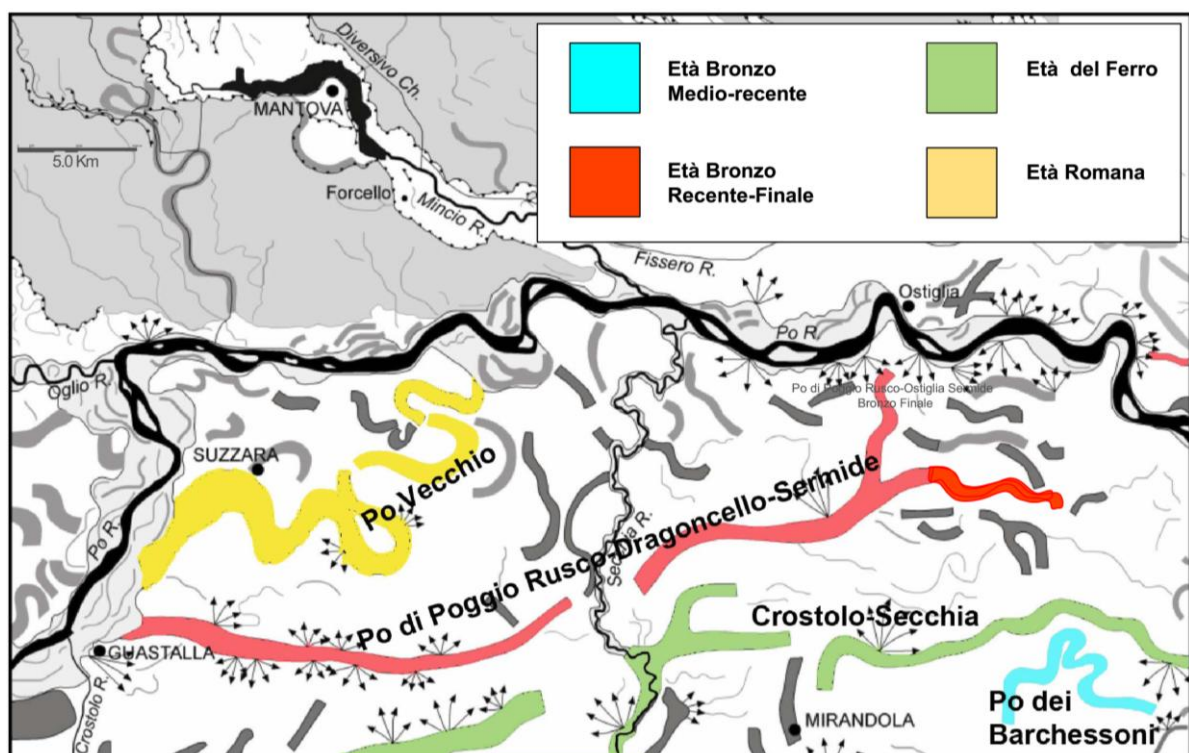


Fig. 17. Schematic map of the main paleohydrographies identified south of the Po di Adria, in the Oltrepò Mantovano-Destra Secchia area, north of Mirandola. There have been highlighted the paths of the Po di Poggio Rusco-Dragoncello-Sermide (a course that replaces the drainages of the Po dei Barchessoni to the north) and that of the Crostolo-Secchia, between the two (in the Gavello-S. Martino Spino area to the south), that start from the Iron Age (modified from RAVAZZI *et alii* 2013).

### 1.3. The paleo-hydrographic situation in the areas of the Southern Veronese Lowland (SVL) and High-Middle Polesine (HMP), north of the Po di Adria.

In the SVL and H-MP area, a sector included between the current course of Po river and that of current Tartaro and Adige rivers, a series of paleo-hydrographic transformations, of almost morpho-climatic origin, occurred between the end of the Early Bronze Age (channels and crevasses-splay conditions: post pile-dwelling site of Canar - Phase I and pre-reclamation site of Canar- Phase II: BALISTA 1998b; DE MARINIS *et alii* 2015) and the beginnings of the Middle Bronze Age (pre-foundation of Canova *terramare* site: VANZETTI 1997; BALISTA 1998a). In this area the morpho-fluvial patterns, identified through very recent photo-geological analysis (BALISTA 2017), initially from anabranching to anastomosed, with very narrow meanders, now appear to acquire single row paths from meanders with a wider radius of curvatures, to more distinctly straight (Figs. 18-19).

<sup>22</sup> Called as Bondeno river in the next fig. 6b, which portrays a situation of V sec. B.C.

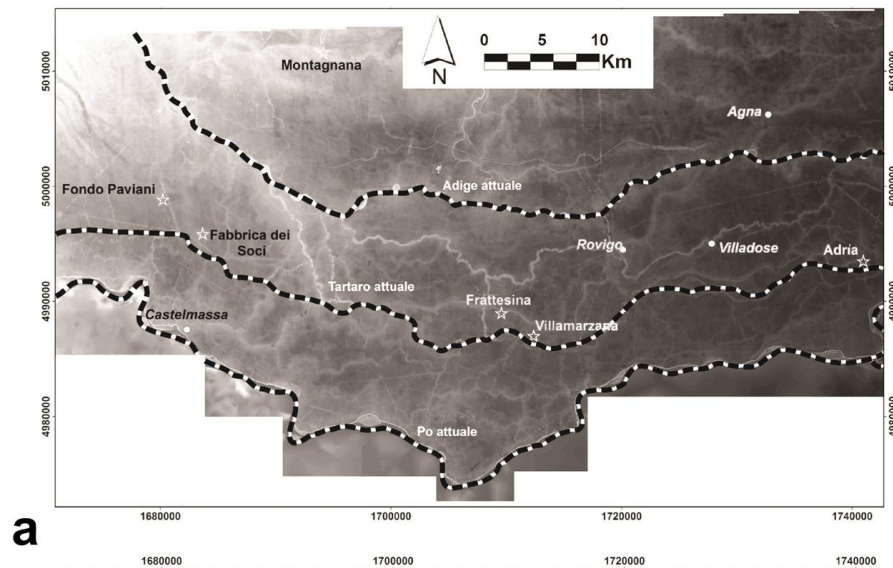
<sup>23</sup> Personal translation of original text in English (see RAVAZZI *et alii* 2013, p. 203).

<sup>24</sup> And in the strip placed 5 km upstream of Castelmassa flowed alongside the Mariconda di Melara 1 and 2 sites, dated between the RBA2 and the FBA1-2 (see FASANI 1966; SALZANI 1973).

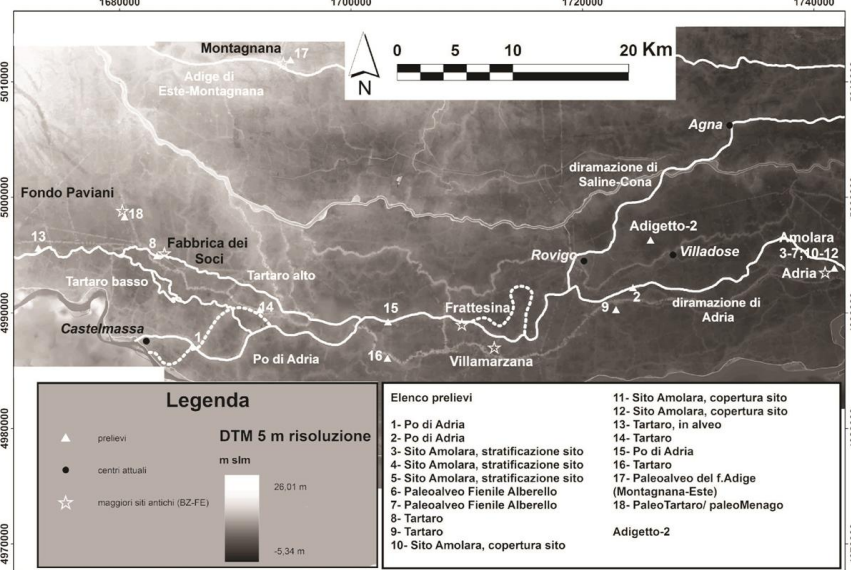


Fig. 18. The territory between the current Adige and Po rivers. Sinuous winding meanders, recently identified between Ostiglia and Castelmassa (in black), have been ascribed to the Canova branch: a post-Canar paleochannel (EBA-MBA1) and pre-Canova site (RBA2). We assigned them to the Po di Adria 1 windings, results of the Löss Oscillation. In this photo-restoration it has also been marked the track of the Po di Poggio Rusco-Dragoncello-Sermide (in white), a new path coming from south-west and cut by the historical Po river course. This new course reoccupied the previous route of the Po di Adria 1, captured the ancient drainages of the Tartaro river and then originated the Po di Adria 1/2. The reactivation of this path strictly connected to the sea (between FBA1 and FBA3), was essential for the emporia and the exchange activities of the Frattesina settlement.

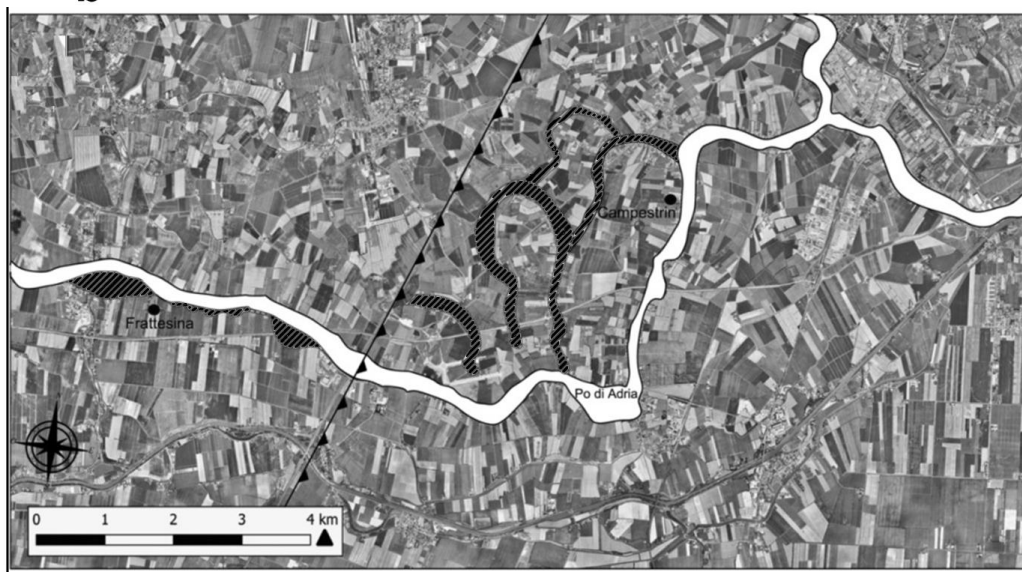
These events are followed by diversions of sections of new channels with effects on the topographic levels of the surrounding groundwaters, whose drainage was poorly governed by Tartaro river, the main axial drainage of the SVL-spring valleys (BALISTA 2009). The formation of important flood channels, such as those of Ceneselli and Campestrin, would seem linked to these paleo-hydrological and paleo-hydrographic disorders, whose stabilization will shortly recall the installation of the peculiar Campestrin site, dedicated to the processing of amber, active between the RBA2 and the FBA1 (SALZANI 2009, BELLINTANI *et alii* 2015) (Figs. 9b1-9b2-B). These groundwater upheavals, as an anthropic response, appear to be opposed by the construction of a long earthwork, the SAM. This large feature was placed to protect the fields of the densely settled agricultural landscape that occupied the rear of the land between Castello del Tartaro and Fondo Paviani from the expansion of peat bogs from the south (BALISTA *et alii* 2016, NICOSIA *et alii* 2011) (Fig. 20). The "dam" feature has returned a range of activities contained between the two calibrated  $^{14}\text{C}$  dates of 1614-1274 BC (*terminus post quem*) and 1371-1051 BC (2s) (*terminus ante quem*) (BALISTA *et alii* 2016). The life stage of the Canova site, strictly contained within the RBA2 (Vanzetti in DE GUIO 1997), *per se* implies a stabilization phase followed by a fast deactivation (about abandonment of the active drainages: BALISTA 1990) of a section of the earlier paleo-hydrography called "Paleoalveo di Canova" whose origin, according to the most recent research carried out in the area, has been referred to a local diversion of the Po river tract (activity derived from the hydrologic cycle triggered by Löss climatic pulses). The site, which is set within a sinuous morphology referable to the remains of an abandoned meander channel (oxbow fluvial lake: BALISTA 2017), is subsequently buried by a thick blanket (1.5 m deep) of alluvial deposits derived from a new reactivation of the flow discharge of the Po di Adria 1<sup>25</sup>, increased from the discharge of the Po di Poggio Rusco-Dragoncello-Sermide between the RBA2 and the FBA1, to give rise to the Po di Adria 1/2 (see *infra*), after a long stability phase overlapping to the local cycle of the large *terrामare* sites.



a



b



c

Fig. 19. In the HMP area, the alluvial ridges linked to the two Po di Adria courses (Po di Adria 1 and Po di Adria 1/2) (a) reveal two different types of paleo-meanders: narrow and sinuous the oldest; straight and larger the newest (b), modifications caused by the increase in discharges. This trend can be seen in various stratigraphic windows from "Castelmassa-Ceneselli Meander" (Fig. 18), to "Arquà Polesine- Campestrin Meander" (c). For both situations we suggest some tectonic and subsidence components linked to the meanders cut off.



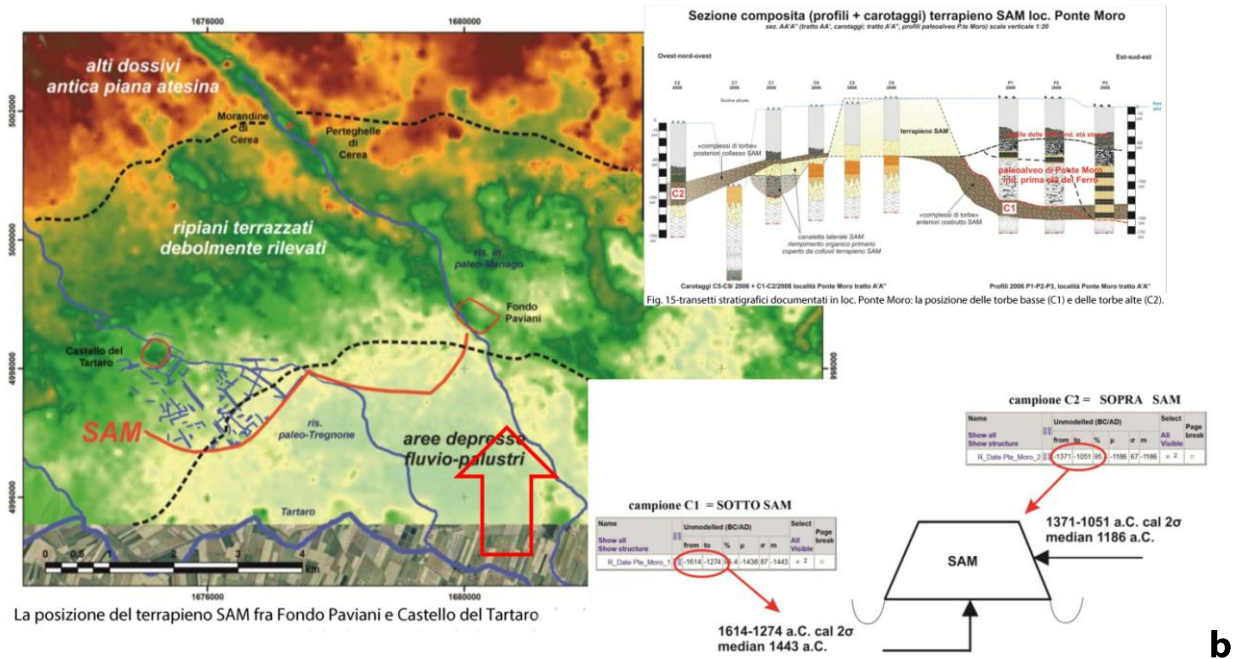


Fig. 20. a) A long embankment (SAM Strada su Argine Meridionale = Southern Embanked Road) could be identified as a counter-reaction to the windings of the Po di Adria 1 river, altered by the new Lössben flows in the SVL / HMP areas. This SAM, an over 8 km long dam, was built and used between 1400 and 1200 BC cal- 2  $\sigma$  (MBA-RBA2) suggested by stratigraphic transects and date  $^{14}\text{C}$  cal. documented at Ponte Moro site (b).

The aforementioned phase of anthropic expansion over the riparian belts of the Po di Adria1, lasting more than three centuries, from the MBA-RBA to the advanced RBA, is concluded before the occurrence of a second wave of paleoenvironmental deteriorations. These, recorded in the area between the final moments of the Late Recent Bronze Age (L-RBA2) and the opening ones of the Final Bronze Age (FBA1), involved mostly a nodal trait of the course of the Po di Adria, the one between Castelmassa and Ceneselli. These processes, to which it seems to correspond also a particular phase of reactivation of the river courses south of the current Po river (see below), have had more recent reconfirmations thanks to the review of a series of paleo-fluvial traces related to the formation of flood channels and splays, that have been documented in correspondence of some channels that flowed into the ditches of Bardellone *terramara* (to excursion from RBA2 to FBA1: DE MARINIS 1987, BALISTA 2007) and Pilastrì *terramara* (post-RBA: see below: DESANTIS 1992; DESANTIS, STEFFÈ 1995; BALISTA *p.c.*), two *terramare* sites located on the ridges of the ancient Dosso di Poggio Rusco-Dragoncello-Sermide and Pilastrì. This singular phenomenon of confluence between the two Po river branches (Po di Poggio Rusco and Po di Adria) has been attributed to a process of reoccupation of a river channel scarcely active by the flow of a more dynamic river channel course recently activated. In this case I refer to the Po di Guastalla (or Bondeno, river: RAVAZZI *et alii* 2013) formed following a regional avulsion that involved (between the EBA and the MBA) the diversion of a part of the flow of the great river starting from a section located between Casalmaggiore and Guastalla. The plausible chronology of this event is supported by the age of foundation (*terminus ante quem*: MBA1: CARDARELLI 2003) of the several *terramare* sites found on the top of the fluvial ridges that opened on both sides of this river belt, before the convergence of their flows into the main central course, called Po dei Barchessoni (BALISTA 2007; CASTALDINI 1989, 1996). The diversion of this stream is caused by the activation of tectonic thrusts, initially small and then more consistent, as evidenced by the morphology of its narrow meanders, abnormally elongated and distorted in the direction normal to the axis of the strike-slip fault, corresponding to the anticline on which is imposed the tectonic thrust of Mirandola, near S. Martino Spino (BURRATO, CIUCCI, VALENSISE 1999). The diversion of the flows of the Po dei Barchessoni to the north (following the new river route of the Po di Poggio Rusco-Dragoncello-Sermide) is attested by the reactivation of the channels, fed by the flows of the Po di Poggio Rusco ridge, linked to the moats of the Bardellone *terramara* (*terminus post-quem*: advanced RBA-FBA, BALISTA 2007) and Pilastrì *terramara* (*terminus post-quem*: advanced RBA). In the meantime, the Poggio Rusco branch was transformed into a local avulsive branch that flowed a short distance from the Po di Adria (Fig. 21). The divergence and finally the confluence of the two branches was marked by the



formation (in the reoccupation spot of the primitive Po riverbed) of a great avulsive fan (*crevasse-splay*) of Castemassa (BALISTA 2017)<sup>26</sup>.

This second and more extensive phase of paleo-hydrographic transformations, which was revitalized by the river dynamism of the northern branches of the Po, is distinguished by two singular properties:

- the water flow of the main river branch appears to be increased by a confluence of the Po di Poggio Rusco-Dragoncello-Sermide (in the branch of the Po di Adria 1) in the section immediately upstream of Castemassa, already marked by a series of re-adjustments in the geometry of the channels of its river belt (see *above*). This would seem to be the moment when the great crevasse splay of Castemassa was formed, within which the main channel of the new course of the Po di Adria 1/2 was defined. This increase in river discharge caused the transformation of the preceding river pattern to meanders with wider radius of curvature, that assumed a decidedly straight course, with single-row path (BALISTA 2017).

- a significant presence of sedimentary load in transit in the river network which implies a greater fraction of sediments mobilized by the destructuring of the anthropic landscape present in the area (now "in gradual abandonment" following the crisis of the *terramare* land managing system (see CREMASCHI 2017). The transport capacity of the new river course would seem to have been strengthened due to the re-occupation of the undersized previous channel (Fig. 21), now crossed by the cumulated flows of the two Po branch streams (the Po di Poggio Rusco and the Po di Adria 1, now defined as Po di Adria 1/2).

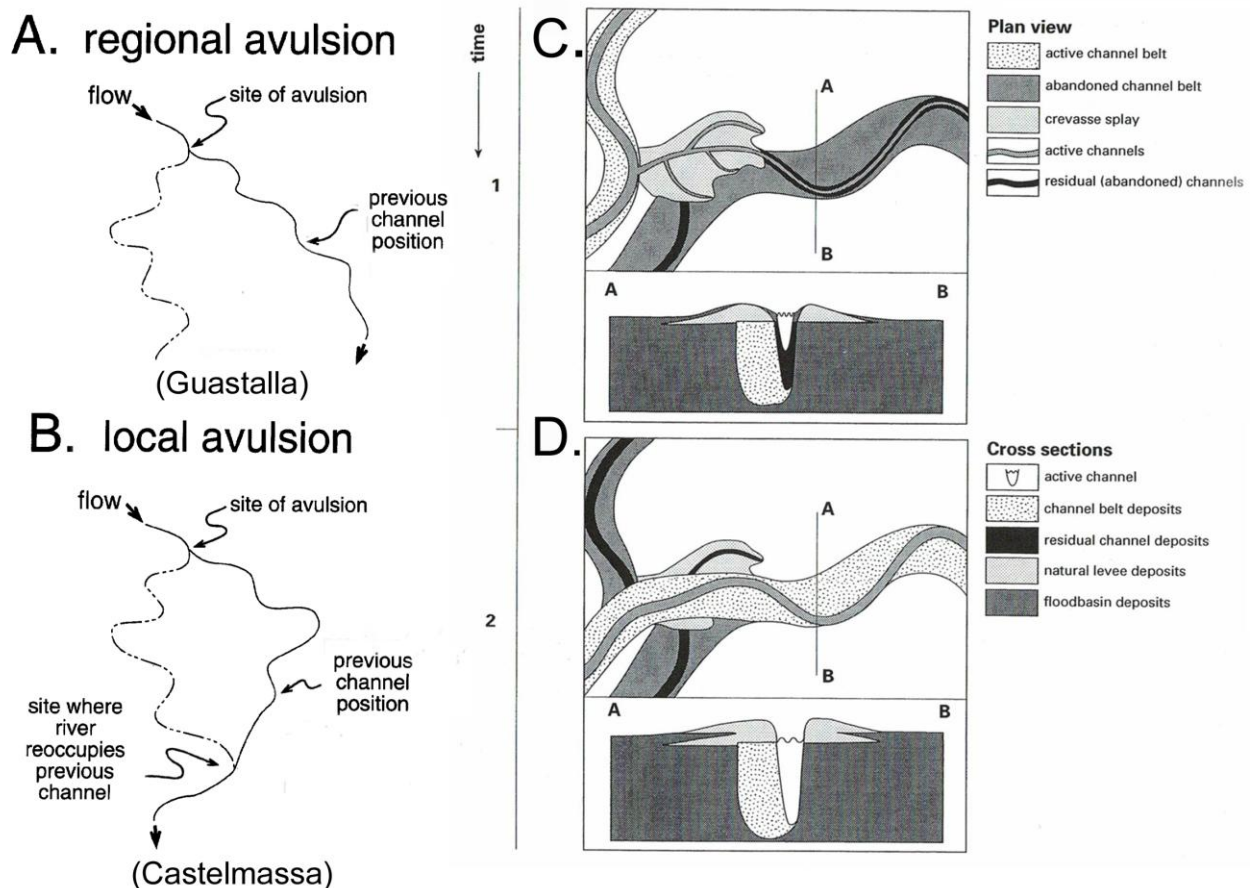


Fig. 21. Conceptual explaining the modifications recorded by the Po di Adria after the confluence of the Po di Poggio Rusco - Dragoncello - Sermide in the Po of Adria 1 (from A to B). This hydrographic node was firstly marked by the formation of crevasse splay fan in Castemassa (C) (see Fig. 18). Secondly the new activity caused a cut in the old meanders of Ceneselli and Campestrin (formation of Po di Adria 1/2: RBA2-FBA1 (see Figs. 18 and 19d). Afterward (D), a new path, with graded regime, was formed and lasted for the entire *excursus* of the Frattesina site (FBA1-FBA3) (modified by HELLER, PAOLA 1996 and from STOUTHAMER 2001).

<sup>26</sup> The notable increase in the flow rate determined a series of changes in the primitive Po di Adria pattern with sinuous meanders, the rectification of which led the formation and the maintenance of a stabilized riverbed, that allowed the flourishing of the new site of the Frattesina and its surroundings.

#### 1.4. The interactions between the disruption of anthropic landscape at the end of the *terramare* “settlement phase” in the territories of the H-MP and the SVL, and a new series of fluvial reactivation processes around the Po di Adria.

As we have seen, a new set of articulated paleo-hydrographic processes marked the development of a second series of paleo-fluvial transformations, which occurred between RBA2 and FBA1, but hence after the conclusion of the settlement cycle of the *terramare* in the investigated area (cycle that took place between MBA and RBA: XVI-XII cent. B.C.). It is worth underlining that this range coincided with an actual stasis in the paleo-hydrographic activities in the whole area of distribution of the *terramare facies* (BERNABÒ BREA, CARDARELLI, CREMASCHI 1997). The several modifications recorded at the end of this mentioned settlement stage, were related mainly to the disruption of large sections of the previous subsistence territories, organized on settled agricultural lands and pasture: see, for example, the flooding of the Canova site and its hinterland. This organization was centered in SVL on the anthropic canalizations fed by captations activated from the spring-valley rivers and then joined into Tartaro river. On the southern edges of SVL, the canalizations of agrarian landscape were connected to the Po di Adria river branches that extended south of Fondo Paviani and Castello del Tartaro sites (CUPITÒ *et alii* 2012). In this regard, it has only recently<sup>27</sup> been possible to identify a network of flood channels that have flow out directly from the Po meanders<sup>28</sup> and that then was abandoned after a phase of extensive modifications to the layout of the ancient Po river belt (BALISTA 2017).

During this phase (between the RBA2 and the FBA1) the fields irrigation networks were dissimilar between the two sectors to the north and south of the Po di Adria: it should argue if this caused a different resilience degree on the local landscapes affected by hydrographic transformations. In the SVL-HMP area, the agricultural support of the sites was based on a canalizations system leaking from the spring-valley drainages, linked then to the site ditches and finally poured into the river Tartaro (the largest delivery of spring-water rivers, affluent on the hydrographic left in the Po di Adria; see BALISTA 2013). In the low Modena-upper Ferrara plains it is mainly attested the use of water captations derived from flood channels<sup>29</sup>, fed by several paleochannels, localized in the super-elevated ridge that crossed those same areas and that frequently caught the groundwater (BALISTA 2007). In the first case (SVL-HMP) must be detected the stability of the feeds deriving from the spring-river outflows, even in the case of climatic crises (i. e. dry spells). In the second case (Modena-Ferrara floodplains), the captations could have a more random result, due to the main paleochannel activity stages from which the secondary channels or canals emerged. In this last case, the advantageous water regime used for irrigation was strictly dependent on the increases in water supplies triggered during the avulsive/re-activation phases of local river belt sections<sup>30</sup>.

It should be noted that in the sectors immediately south of the Po di Adria (territories of the low Modena-High Ferrara floodplains), the diversion of the new and wide river belt of the Po di Poggio Rusco-Dragoncello-Sermide caused the burial of a large strips of alluvial plain where were located the *terramare* sites and their related subsistence territories (agricultural and livestock) of the MBA-RBA phases. Contemporarily the significant modifications of the Po river network that occurred between the RBA2 and the FBA1 in the north-eastern sector from Castelmassa to Badia Polesine, had a strong impact on the entire area belonging to the southern sector of the SVL, coinciding with the *chiefdom* of Fondo Paviani (CUPITÒ *et alii* 2015a). This territory was crossed by drainages channels connected to the confluence of the Tartaro river in the Po di Adria 1: the reactivation of the Po di Adria discharges, derived by reoccupation of its channels (Po di Adria 1/2), caused serious (negative) consequences on the "hydraulic efficiency" of the local paleo-hydrographic networks of anthropogenic origin, activated in previous time and centered on confluence of the Tartaro into the Po di Adria (BALISTA 2009).

It could be concluded that while the southern sector was almost entirely damaged, flooded and abandoned, the northern one was able to acquire a greater resilience degree. In fact, the only surviving big *terramare* site, Fondo Paviani<sup>31</sup>, was in the northern sector, where was possible to exploit the spring valley feeding canals till the end of the FBA1.

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<sup>27</sup> Based on the results of petrographic analyses carried out on the sands of paleochannels ridges that crossed the territory between Tartaro and Po di Adria rivers (BALISTA 2017).

<sup>28</sup> From the meandering places further north, already in a partial state of abandonment after the phase that involves the formation of the route-channel that floods Canar phase I and the route channel that will be later used by the site of Fabbrica dei Soci to feed its ditch.

<sup>29</sup> Even if they had ephemeral duration and very often were in quiescent stage.

<sup>30</sup> We should reflect on the size reached by the great sites, caused not only by the repositioning required by the demographic increments but also by the necessity to move the population in more suitable locations served by the feeds from the new avulsive pathways of the regional river network.

<sup>31</sup> Together with its subsistence territory.

## 2. THE FRATTESINA SITE<sup>32</sup> LOCATION IN THE CONTEXT OF THE DEPOSITIONAL COMPLEXES DOCUMENTED IN THE PO PLAIN AND DELTA DURING THE FINAL BRONZE AGE.

The Po di Adria after having crossed the lower floodplain territories on the border between the Po and the Adige historical fluvial domains (near the apex of the ancient sectors of delta, already during the EBA), forked in two separate branches: that of Saline-Cona to the north-east and that of Adria to the east-southeast (PIOVAN, MOZZI, STEFANI 2010) (Fig. 22a). The beginning of the fluvial aggradation activities within these two ancient river branches has been proposed for Cona starting from ca. 2192 BC cal. (4237-4979 cal BP) and for Saline starting from ca. 2288 BC cal. (4141-4712 cal. BP) (PIOVAN, MOZZI, STEFANI 2010) (Fig. 22b-c) Therefore, to achieve a substantial assessment of the characteristics and the evolutionary phases of this singular waterway (Saline-Cona) suddenly extinguished at the end of the Bronze Age (see *infra*) these fluvial segments should be evaluated within the longest chronological stage which includes the entire cycle of activity of the ancient main northern Po river branch<sup>33</sup>. The range of activity of these two branches took place between the EBA and the FBA (PIOVAN, MOZZI, ZECCHIN 2012). I should focus on the possible correlations between the stages of activity-transformation-abandonment of these two important Po di Adria distributary outlets (to the sea), and the phases of activity shown by the Po di Adria on the "section-type" of the Frattesina site recently recorded (Balista in BALDO *et alii* 2018). From this section, related to a monocursal Po channel (not yet divided into its delta distributaries) were derived significant data on depositional complexes sequences whose units constituted a direct expression of the river regimes during its life activity.

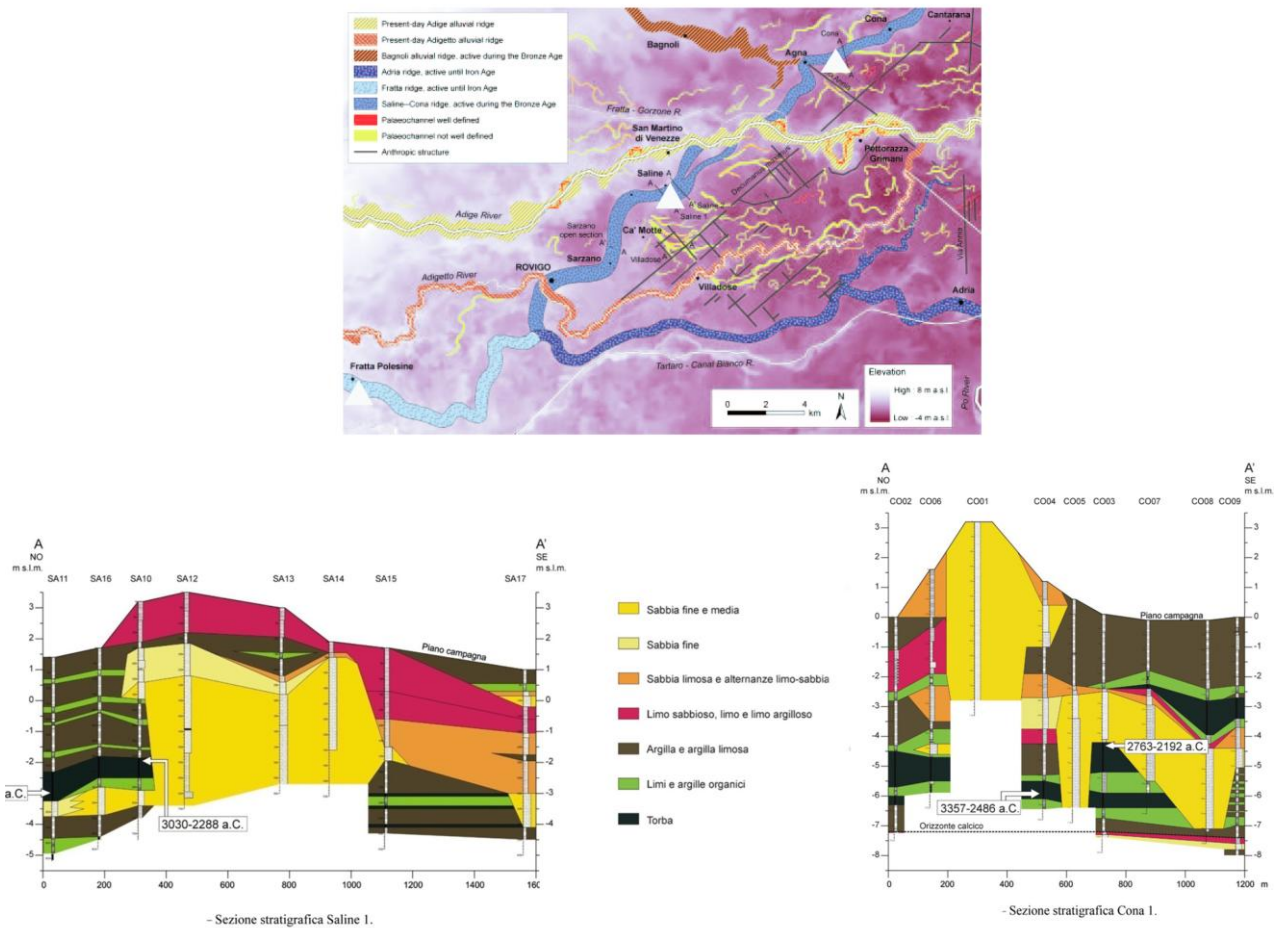


Fig. 22. The sections of Saline 1 and Cona 1 (white triangles in the map), located on the branch of Saline-Cona ridge in the ancient Po di Adria upper delta plain. The sample points come from layers located on the side of the old channel. In the both cases it is observed how the fluvial channel does not involve an erosional lateral contact with the fluvial-marsh basin stratifications that surrounded it, but it is inserted between them ( from PIOVAN, MOZZI, STEFANI 2010 ).

<sup>32</sup> The data relating to the recent sedimentological and geomorphological investigations carried out in the territory of Fratta Polesine are part of the "Frattesina Project" for which we refer to what is published on the volume LIV of Padusa (BALDO, BALISTA, BELLINTANI 2018).

<sup>33</sup> It spanned since the end of the III throughout the II millennium B.C., up to the first centuries of the I millennium B.C.



Some chronostratigraphic and paleo-hydrographic connotations of immediate interest, derived from investigations performed by Piovan (PIOVAN, MOZZI, STEFANI 2010) on the exposures of the Saline site, allow us to reconstruct the local geomorphological situation of a middle-Polesine sector "fossilized" at a date close to 3000 cal. BP, roughly equivalent to that known by the initial installation of the Frattesina site (see below). At this moment the fluvial structure of the two branches is highlighted by the abandonment stage in which the northern branch is (that of Saline-Cona ridge: PIOVAN, PERETTO, MOZZI 2006), while the southern one (that of Adria ridge) becomes predominant for a partial avulsion of the active flow rates of the first. The phase of abandonment of the Saline branch would then be pre-dated by the settlement layers of the eponymous site (dated between the XI and X centuries B.C.: Frattesina 2 phase (BELLINTANI 1986). Those layers growth up on the surfaces of the natural banks of the relict fluvial course, in continuity with the surfaces formed at the roof of the clayey deposits of the central channel in abandonment stage, now no longer fed by the main flows of the Po (Balista in BALDO, BALISTA, BELLINTANI 2018) (Fig. 22b).

These considerations offer the starting point to detect a further consequence of the avulsive processes that affected the paleo-hydrography of the contemporary Po di Adria delta area. The early occlusion of the Saline-Cona branch, due to the diversion of the Po river discharges (in transit in the Po Valley between Castelmassa to Frattesina) turns out the entire Po river flow into the Adria branch. The concentration, and therefore the strengthening, of the Po river flows on this branch, would offer a prompt "cause-effect relationship" with regard to the deep erosive event that impacts the site of the MBA-RBA of the Amolara di Adria (probably recently abandoned?): a catastrophic diversion of the fluvial course, which previously had to flow (more quietly) nearby the site<sup>34</sup> (BALISTA 2013; GAMBACURTA *et alii* 2018)(Fig. 23a-b).

This event could have caused some disarray in the extension and therefore in the efficiency of the northern Polesine deltaic sector (previously strengthened by the confluence of the flows of the Adige river (by "Bagnoli ridge": PIOVAN *et alii* 2012) in the Saline ridge. The activation of the erosion channel that impacts the site of Amolara may have marked a moment of temporary unavailability of the mouth of the Po di Adria, now fed by the most voluminous of Adria branch. This bulky hydrographic event, in turn, may have caused the progradation of its new estuary apparatus, with the consequent extension towards the sea of the river belt of the Po di Adria (VEGGIANI 1972, 1974; PERETTO 1986 and PERETTO, BEDETTI 2013). Finally, there will be a subsequent re-adjustment of coastal paleo-hydrographies, thanks to the stabilization of the new river mouth of the Adige river, now separated from the Po river at east/south-east.

From this moment on, thanks to the strengthening of the Adria branch course, it developed an extended hydrographic stability phase that was favored by the acquisition and maintenance of a graded equilibrium profile of the main channel of the Po di Adria and its fluvio-deltaic southern branch. This new state of river equilibrium was now favored by the direct connection of the Po river course between Castelmassa and Frattesina with the sea mouth in the new Po di Adria 1/2. This situation marked the beginning of a long period of greater economic flourishing of the site-emporium of Frattesina and shortly after (or in continuity ?) that of the Villamarzana site (ARENOSO CALLIPO, BELLINTANI 1994; SALZANI 2001; CONSONNI, SALZANI 2005; CONSONNI 2008).

After more than a century (IX-VIII cent. B.C.), new paleo-hydrographic and paleo-environmental situations were established in the Polesine coastal area, determined by the turnover of different paleoclimatic conditions linked to the arrival of the cold-wet Göschenen I Oscillation, that marked the beginning of the Sub-Atlantic Period (MERCER 1967; VAN GEEL *et alii* 1996, 1998; VAN GEEL, RENSSSEN 1998). This climatic modification, associated with an increase in annual water budget and sediment depositions, together with an extension of the river course (which resulted in a decrease in the slope of the riverbed) seems to have determined the trigger for an extensive phenomenon of rapid over-flooding by back-filling of the Po di Adria (Po di Adria 2). At the end, a complete (and rather rapid) avulsion of the flows of the Po di Adria occurred at the regional avulsive knot of Castelmassa leaving as testimony a new impressive ridge from there to the sea.

The river branch of the Po di Adria would therefore cease its activity following the avulsive route of Sermide flood, which was attributed, based on paleo-topographic and foto-aerial & geological researches led by Ferri (FERRI 1985) and accepted by the totality of scholars, to paroxysmal events occurring concurrently with the transition to the Sub-Atlantic climatic period of the Holocene.

These events occurred between the IX and VIII cent. B.C.<sup>35</sup> and led to the abandonment of the entire Po river belt of Polesine, leaving a new path for the Tartaro river, and directed its discharges to re-activate a southern Po branch called thenceforth as Po di Spina (BONDESAN 2001, BALISTA in GAMBACURTA *et alii* 2018: see below Fig. 15), but in fact coinciding with a tributary branch of a Po di Ferrara course fed by Secchia & Panaro rivers after Bondeno and Reno river after Ferrara.

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<sup>34</sup> The paleochannel of Fienile Alberello, a local denomination of the "Adria branch" of the Po di Adria (BALISTA 2013).

<sup>35</sup> A dating based exclusively on paleoclimatic order deductions (Sub-Boreal/Sub-Atlantic transition) and only partially, and indirectly, supported by the absence-presence of Final Bronze-First Iron Age 1 sites in the lateral stretches affected by the avulsive path.

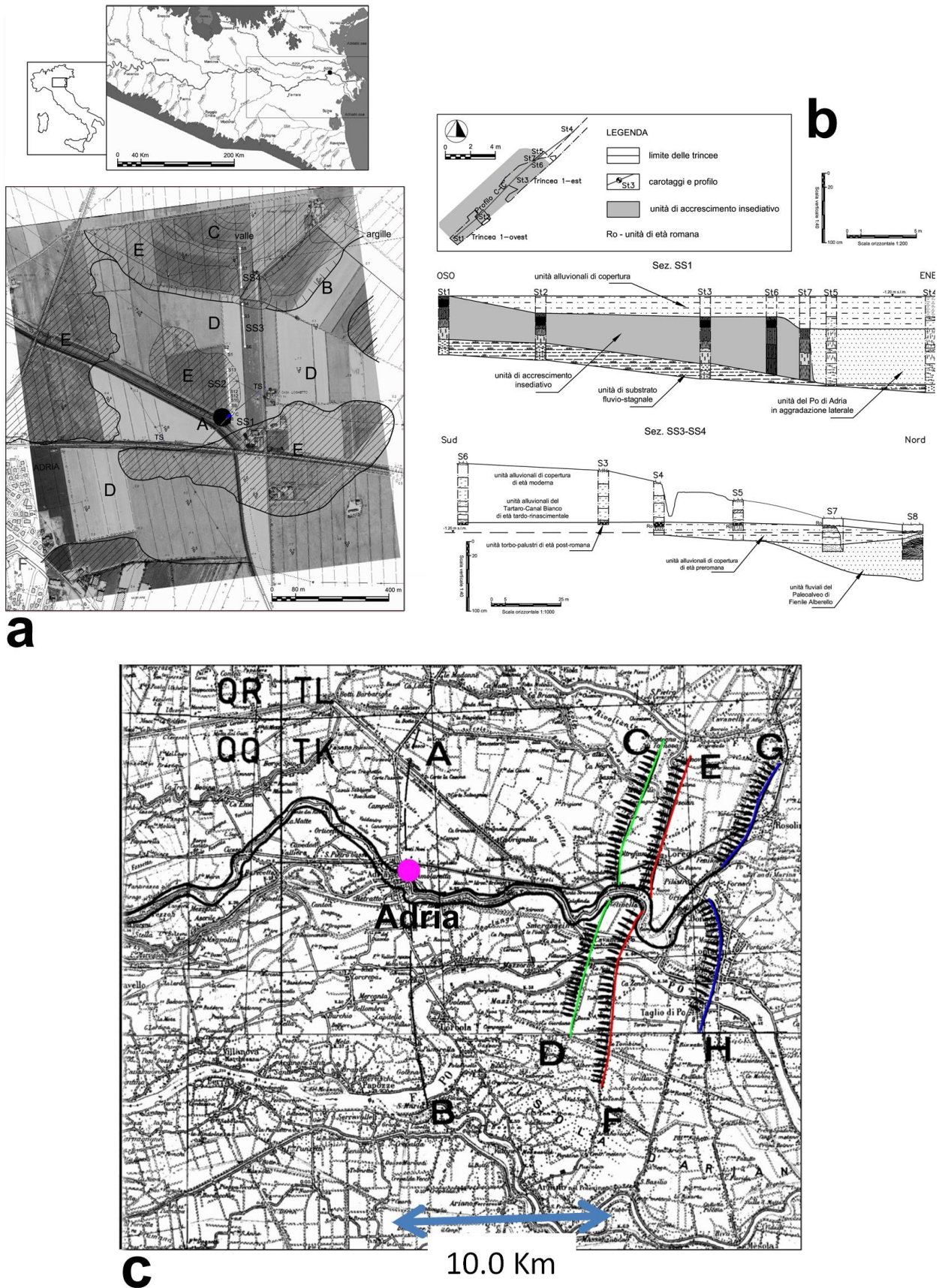


Fig. 23a-b. Adria-Amolara site map and sections. On chrono-typological basis, the upper stratifications of the site display evidence of advanced RBA1/beginning RBA2 presence; on an absolute chronology basis, a date of 2976 +/- 45 BP; 1320-1050 cal to 95.4% remarks this age. The erosion of the site was ascribed to a river stage marked by reactivation episodes fed by the Po di Adria 1 discharge, probably during the same phase in which the transformation in the Po di Adria 1/2 occurred. In the topographic map of fig. 23c are marked the three coastlines ascribed by Veggiani (1972) to the Bronze Age (CD), the early Iron Age (EF) and the advanced Iron Age (VI-V century B.C.) (GH).



## 2.1. The $^{14}\text{C}$ -AMS dating set of the Frattesina site upper substrate layers.

The settlement of Frattesina di Fratta Polesine (BIETTI SESTIERI 1981; BALDO, BALISTA, BELLINTANI 2018), raised in close proximity to the Po di Adria right bank, is flagged by a particular geographical location: it was situated less than ten kilometers upstream of the bifurcation from which originated the two Po di Adria deltaic branches mentioned above, at the transition between the extremes of the lower floodplain and the first basins of the upper delta plain (Fig. 24).

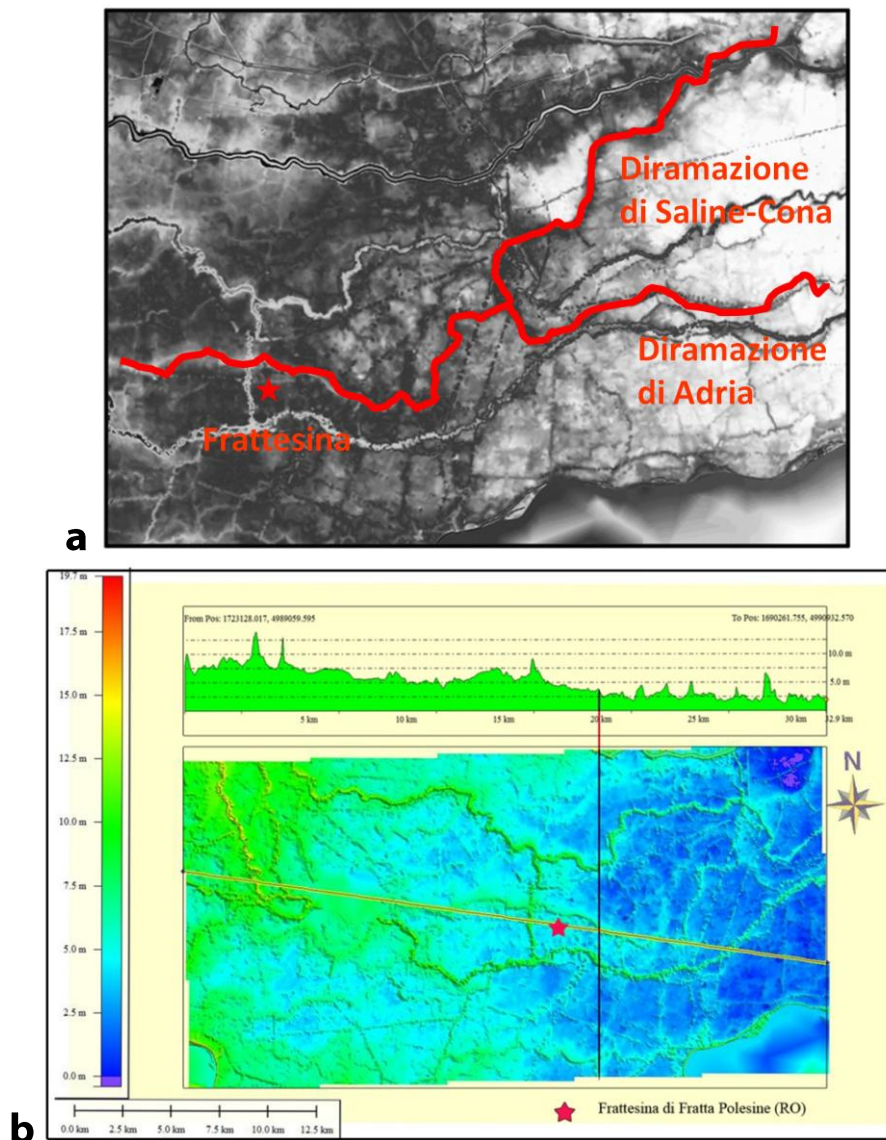


Fig. 24. The Frattesina site arises at the apex of the delta system belonging to the Po di Adria 1/2, at a short distance inland of its bifurcation towards Saline-Cona and Adria ridges. The site's altimetric position is clear, above the average elevation of the neighboring fluvio-palustrine basins (between 7.5 and 4.5 meters above sea level), which at the time was largely flooded.

The  $^{14}\text{C}$  dates of the most recent peaty horizons of the palustrine basin sequences that precede the first fluvial stratifications on which the site of the Final Bronze Age of Frattesina is founded (see Balista in BALDO *et alii* 2018), come to put the first stake to interpolate the position of the site stratigraphic complexes in relation with the High and Middle-Lower Polesine regional Holocene series, already partially proposed by PIOVAN *et alii* (2010 and 2012). The three dates acquired shortly forerun the installation of the site (with date known by cultural materials) which is positioned on the surfaces of an extensive "crevasse splay" generated by a burst opened on the right hydrographic side of the ancient Po di Adria1/2. The dates are referred to a moment of partial drying and of reforestation the local stagno-palustrine basin <sup>36</sup>, which occurred between the glimpses of the Late Bronze Age (RBA2) and the beginning of the Final Bronze Age (FBA1) (for chronology see: BELLINTANI 1992; BAGOLAN, LEONARDI 2000; Fig. 25b). The following

<sup>36</sup> Situation deduced from the presence of woody twigs inside the matrices of the detrital peats in evident oxidation condition. From the mechanical coring of these peat units we extracted the undisturbed samples of the immediate substrates of the site (Balista in BALDO *et alii* 2018).

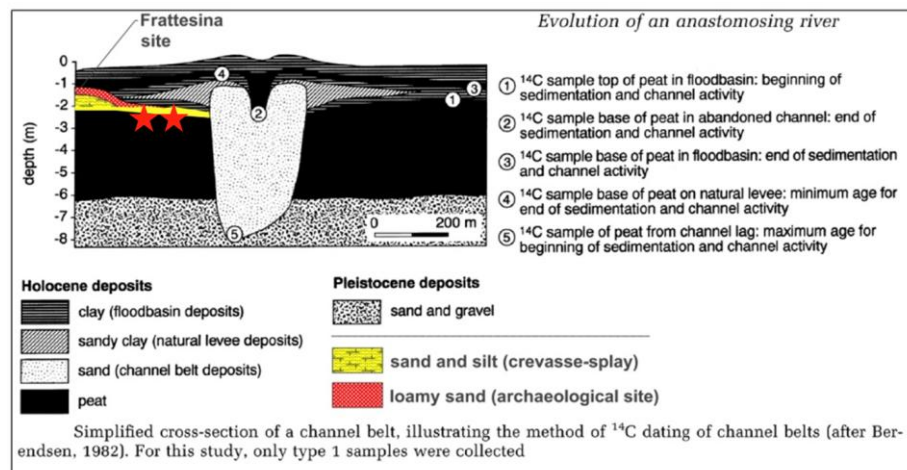


table shows the set of the three  $^{14}\text{C}$ -AMS dates acquired by mechanical undisturbed cores carried out in the immediate substrates of the Frattesina site (2016-2017 fieldwork excavations)<sup>37</sup>.

Campione	Codice CEDAD	Datazione $^{14}\text{C}$	calibrata*( $2\sigma$ )
Frattesina FASE O CM3 1A	LT 1644 6A	3029+/-35 BP	1410 BC (93,9%) 1190 BC
Frattesina FASE O CM3 1B	LT 1644 8A	3005+/-35 BP	1310 BC (84,8%) 1120 BC
Frattesina FASE O CM4 1A	LT 1644 7A	2894+/-45 BP	1220 BC (93,9%) 970 BC

note \* The  $^{14}\text{C}$  dates of the analyzed samples were calibrated in calendar age using the OxCal software vers. 3.10, based on atmospheric data (REIMER *et alii* 2013, Radiocarbon 55 No. 4-1869-1887).

The sandy-silt platform of the crevasse splay (Fig. 25a) (the result of a limited episode of river flooding that ended locally without giving rise to a more long-lasting flood channel) constitutes the paleo-hydrographic evidence of a first major fluctuation in the course of the nearby paleochannel of the Po di Adria. On that platform, where will raise Frattesina, were dug, since the beginning, a series of straight dry ditches (not fed by constant water flows), that divide into regular sectors the site.



**a**

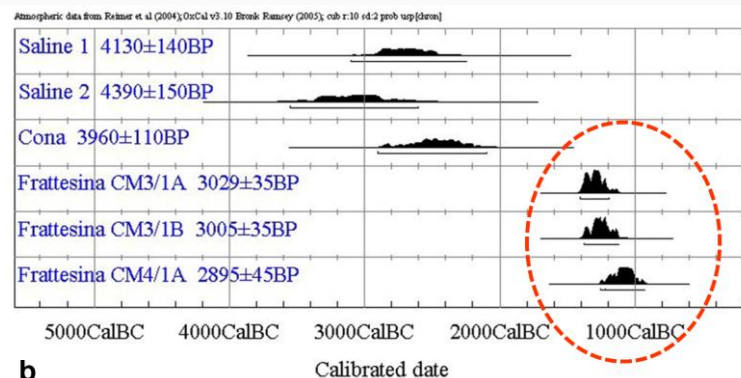


Fig. 25a-b-c-d. Frattesina site is located above a "burst fan" originated by a crevasse-splay deposition fed by the Po di Adria 1/2 (yellow layer) and placed at the roof of a fluvial-palustrine and peaty sediments sequence (cfr. Fig. 26) (deposited between 1220 and 970 cal BC: table in text and b; red stars: peat sampling points). The alluvial and the anthropogenic complexes of the site were buried by flood deposits of the pre-abandonment phase of the Po di Adria 2 (post-Frattesina-Phase 3: ca. 9th-8th B.C.).

<sup>37</sup> The three recently acquired  $^{14}\text{C}$  dates for the peats in the immediate substrates of the Frattesina site (all included within a range very close to the end of the RBA phase (RBA2-FBA1), would therefore refer only to a moment immediately preceding the occurrence of the indicated above episode of reactivation of the Po di Adria 1/2 discharge. Once reabsorbed, this wave of flows beyond the average, caused by the confluence of the Po di Poggio Rusco in the Po di Adria, the river regime stabilized and there was reduction of the annual average discharges caused by the prevailing continental-dry climatic conditions. The protracted "graded/balanced" activity that followed (between the FBA2-FBA3 and the E IA1) seems to have had considerable positive effects for the settlement in the central-lower Polesine area, especially during the Frattesina florescence, when a favorable socio-economic coincidence was established, thanks to dynamic interactions between Mediterranean and Adriatic traffics/exchanges.

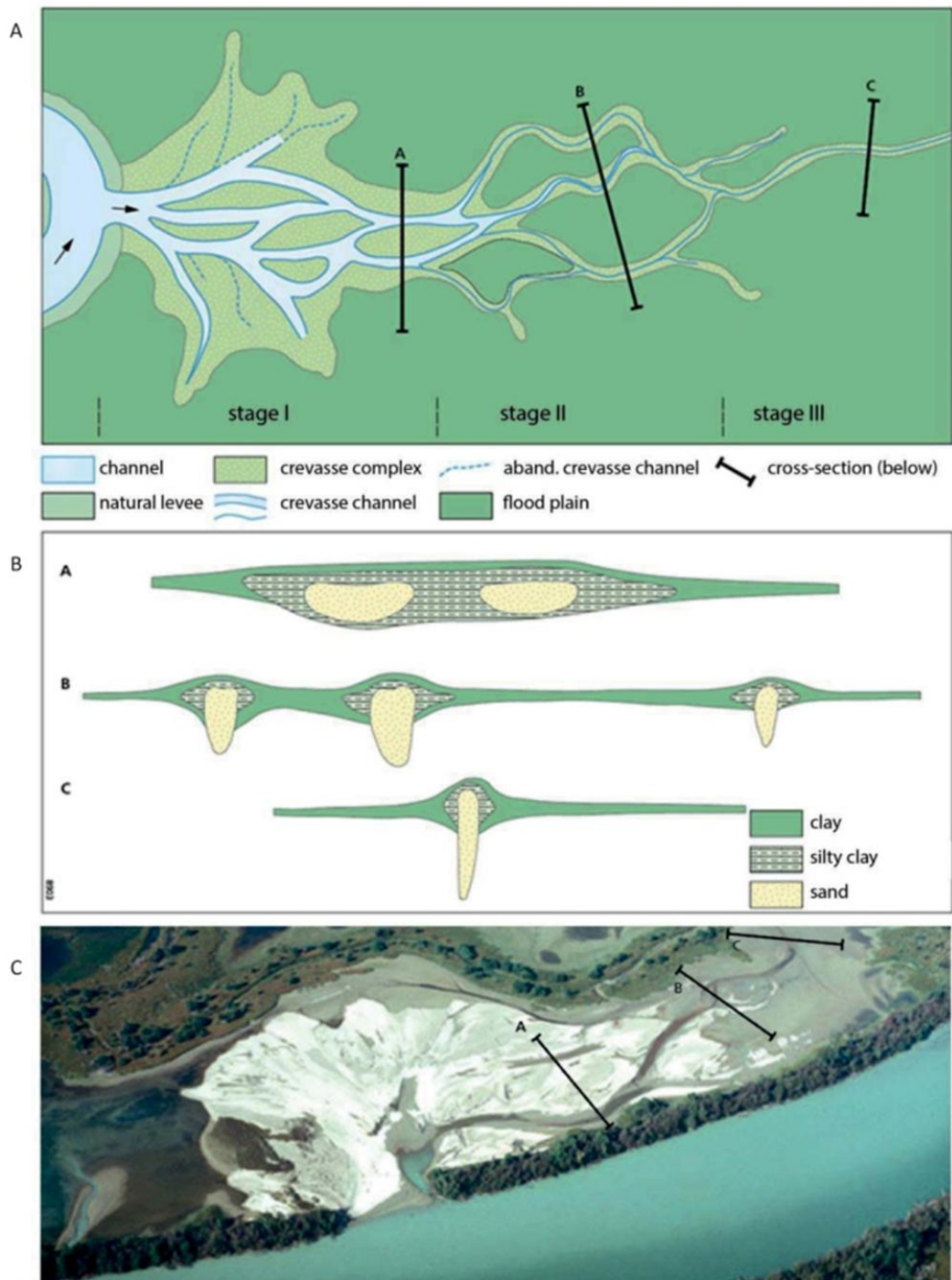
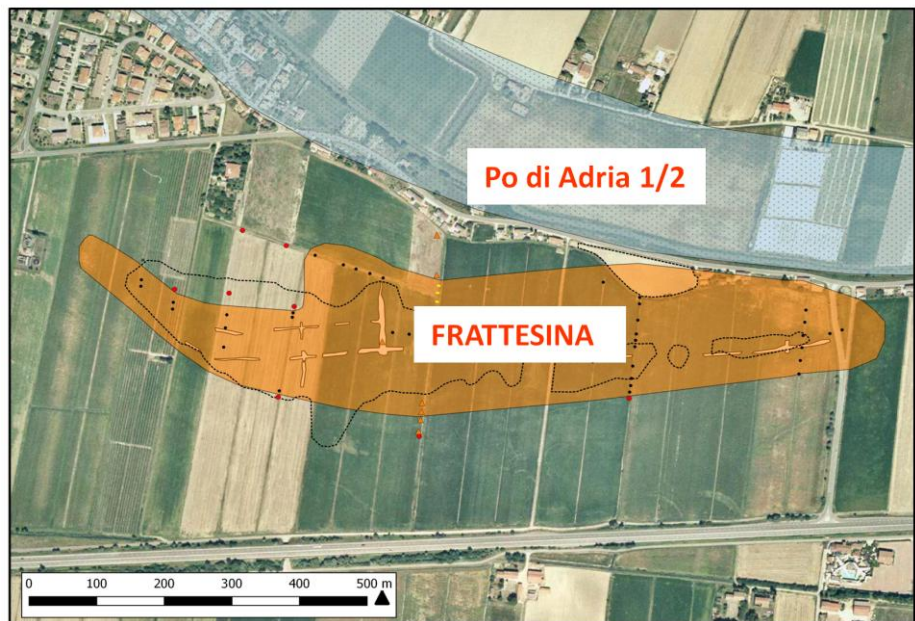


Fig. 26. Schematic cartoon with plan, sections and exemplary photo comparable to the fluvial basement of Frattesina site, located above a "burst fan" originated by a crevasse-splay deposition fed by the Po di Adria 1/2. Map and lithological architecture from STOUTHAMER 2001. Image displays a natural crevasse splay in the Columbia River (foto H.J.A. Berendsen).

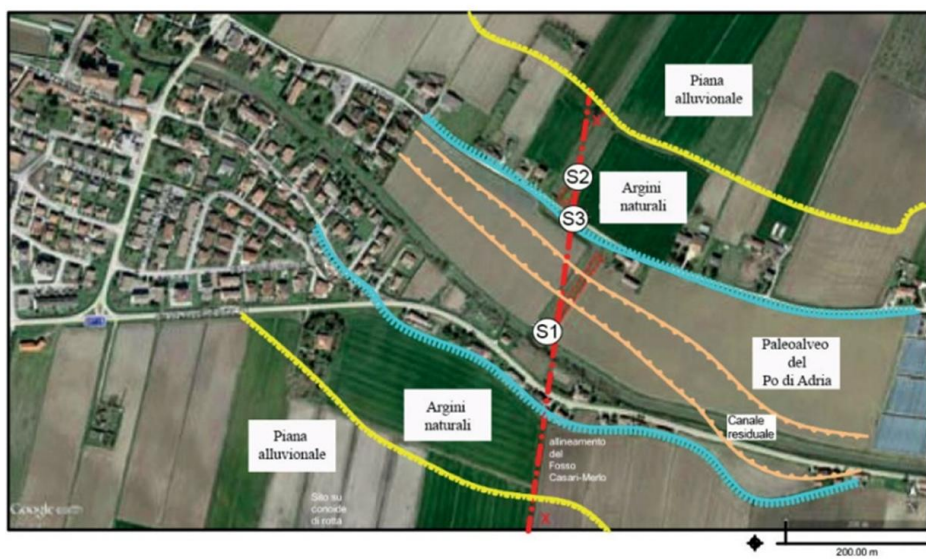
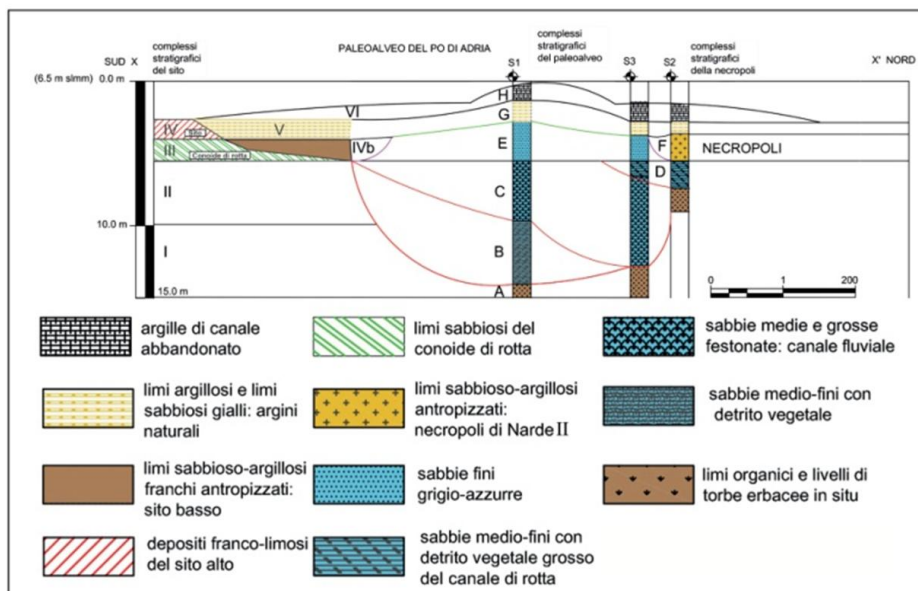
The site extends over an area of approx. 20 hectares and maintains an average archaeological deposit thickness of 0.5-1.5 m. (Fig. 27)<sup>38</sup>. The site developed in the immediate vicinity of the natural banks of an impressive river channel, the Po di Adria 1/2, that have an average width of 275-300 m and a depth of 10 and 13 m, to which currently corresponds a fossil paleochannel ridge, which rises between 1.5 and 2.5 m on the surrounding ground level, placed at altitudes of 3.5-4 m above sea level (Fig. 28).

<sup>38</sup> Relatively small thickness due to a consistent agrarian leveling carried out in the years ' 50 of the last Century.





a



c

Fig. 27. Site plan, schematic stratigraphic profile and ge archaeological sections' alignment recorded between the site of Frattesina (extended through 20 ha ca) to the south, the Po di Adria paleochannel in the center, and the Narde II necropolis to the north (from the Frattesina Project, 2016-2017).



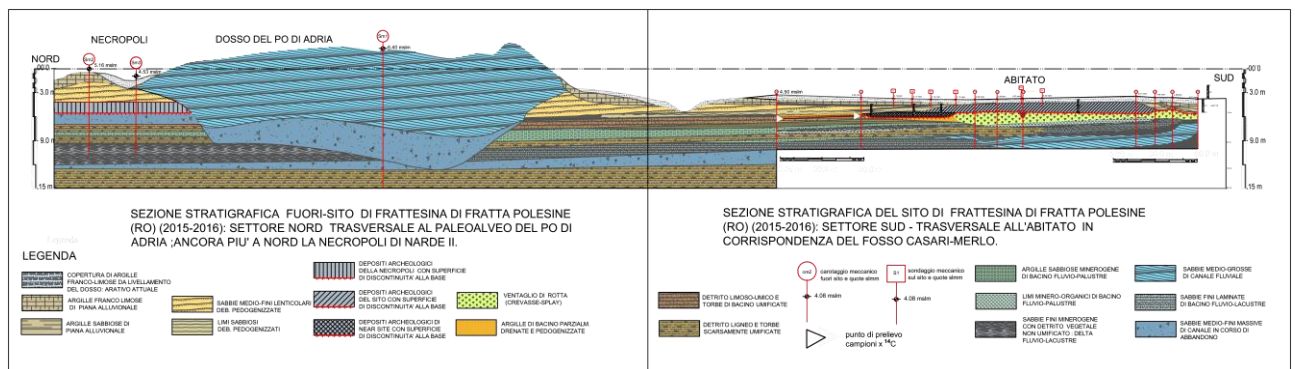


Fig. 28. Cross section of Frattesina site (seen from the west) according to a stratigraphic transect recorded between the Fosso Casari Merlo and the Po di Adria paleochannel. Site dimensions: site area =ca. 20 ha; site width: 175 m ca.; fluvial ridge width: 315 m ca.; site stratifications residual thickness: 1.0-1.5 m ca.; paleochannel depth: about 15 m above ground level; super-elevation of the ridge to the site: 2.0-2.5 m ca.

After this episode of more vigorous paleo-fluvial dynamism, although of short duration<sup>39</sup>, the paleochannel appears to have continued its hydraulic activity with a fluvial regime less subject to full pulsations than the average, having reached a more stable "graded" regime (in conjunction with the unfolding of a continental-dry climatic phase : see CREMASCHI *et alii* 2016). This phase, lasting about three centuries (from the 11th to the 9th century B.C.), correspond with the settlement range of the site itself (ARENOSO CALLIPO, BELLINTANI 1994; Bellintani in BALDO *et alii* 2018). For the same range here considered has been examined the sections of the Narde II necropolis (SALZANI 2010: illustrated in detail by DI ANASTASIO 2010) as evidence of a prolonged period of relatively balanced regime acquired by the great river. In the necropolis are widespread the thin depositional units as result of weak overflows<sup>40</sup>, which are limited on the terraces of the river's natural banks in the form of sub-decimetric layers of slow tabular growth<sup>41</sup> (Fig. 27b).

The reconstruction analysis of the natural environment associated with the aforementioned sequences (even if the samples were derived exclusively from the pollen study of the contents of the necropolis burning-places, see MARCHESINI, MARVELLI 2010), highlighted how this context evolved in correspondence with "an extended meadow" probably coinciding with a sort of holm (*golena*) that developed between the main riverbed (then still incised), and the more undulating ridges of the natural banks. The observed coexistence of oakwood and hygrophilous bushes could imply a moderate degree of *xerophyllia* favored by the continental-dry climate component prevalent at that time on the Frattesina site. It should also say that there was only one episode of overflow / flooding within the stratigraphic sequence of the site beyond the one that originated the site's sandy-silty formative fan. An isolated episode of sandy overflow, whose limited extension was recently detected in detail (BALDO *et alii* 2018, fig.10) would be the only exception. This second fluvial unit, referable to the deposits of an isolated burst episode would seem to coincide with the alluvial episode recorded from PALMIERI (1981) on the section of the central ditch of the site: based on the pottery chrono-typology, it would correspond to a late episode, interposed in the sequence of the site, which occurred between stages 2 and 3 of Frattesina (Bellintani in BALDO *et alii* 2018)<sup>42</sup>.

The composition and stratigraphic position recalled for the carbonaceous cremation deposits unearthed in the two necropolis of Fondo Zanotto (BALISTA 1982) and of Narde II (DI ANASTASIO 2010) seems the same: the carbonaceous deposits of unit IIIa in Fondo Zanotto and of US 1109 in Narde II, separate the units of the lower necropolis depositional complex from the upper one. In both sites, the two superimposed stratigraphic complexes developed in an almost analogous way: the lower one grow directly over alluvial substrates, while the upper one, much more remodeled, is sourced by more thin overflow deposits. The carbonaceous episodes end with a disconformity surface (an exposure surface, partially eroded), that prelude the setting up in area of a sequence of deposits outcome of weaker river activity and with flood peaks much more contained than the previous one. The break between the two complexes, based on the chrono-typological seriation of the buried contexts brought to light in Fondo Zanotto (DE MIN 1982, 1986, DE MIN, GERARDINGHER 1986), would fall roughly between the end of XI cent. B.C. and beginning of X

<sup>39</sup> The short persistence of this burst-channel from which the alluvial fan was formed, is inferred from the morphology, the limited thickness and the discrete extension of the silty-sandy body that originated the substrate layers of the site. Of course, even the short chronological gap between the dates of the peaty horizons below and those of the oldest chrono-typological materials found at the base of the site, are all the elements that reinforce this assertion.

<sup>40</sup> Result of floods of limited entity, perhaps in a multi-year cadence, among which the dedicated surfaces to the burials are inter-layered.

<sup>41</sup> It is reiterated that during this phase there are no episodes of paroxysmal floods, such as the US 1123 (SALZANI 2010) which concludes the sequence of stratifications of the Narde II necropolis, nor on the site, such as those which determined the extended coverage of peripheral areas of the site (BALDO, BALISTA, BELLINTANI 2018).

<sup>42</sup> It, however, would seem to herald the beginning of those disastrous paleo-hydrographic deteriorations that will lead, shortly thereafter, to the abandonment of the area settled, for the total flooding of the site and its hinterland (see *infra*).

cent. B.C. (the first one), and between the half of the X and the beginning IX cent. B.C. (in the Narde necropolis). These chronologies would correspond, in the contexts of Narde II to a range from the end of RBA to the FBA1 for the lower phase (phase 1), and from the FBA2-3 to the beginning of the Iron Age, for the upper phase (phase 2) (see SALZANI 2010). It should be investigated if and how the two depositional complexes of the two Frattesina necropolises, (separated by a similar range of burning earth, quite analogous for composition, depositional structures and cultural elements) are linked to the modified river systems controlled by the transition from Po di Adria 1 to the Po di Adria 1/2 regimes.

### **2.3. The chronological gap returned by the sections of Saline-Cona ridges in relation to the dates obtained from the section of the Frattesina site. An apparent contradiction...**

At this point some considerations have to be made in relation to the apparent chronological discrepancy given by the much older dates of the clayey/organic and peaty horizons considered in phase (or slightly earlier) with the aggradative phases of the paleochannels recorded on the Saline-Cona branch (PIOVAN, MOZZI, STEFANI 2010) (see fig. 22b-c and Fig. 25b), by comparison from those (much more recent) obtained by the upper peaty layers of Frattesina site. It should be noted that the latter one (of Frattesina) would have shortly preceded the formative episodes of the natural banks and of the connected crevasse splay<sup>43</sup> emanating from the Po di Adria (that we called the Po di Adria 1/2)<sup>44</sup>. In fact, the positions of the <sup>14</sup>C samples coming from the sections of the above-mentioned two sites (located on the same ridge: Saline-Cona; see PIOVAN, MOZZI, STEFANI 2010), clearly indicate how the samples were taken at different depths rather than in correspondence the most surficial horizons of the relative alluvial basins within which the two paleochannels sections are inserted. Since it is believed that the clayey-organic and silty-clayey deposits of the alluvial basins (within which the peat horizons are interposed) are formed during the occurrence of episodes of greater reduction in the flow rates in the river channels (with which they are in relation of lateral facies (GOUW, ERKENS 2007; GOUW 2007) it is deduced that in these areas the aggradations in the channels have actually started in relatively older times than those documented at the top of Frattesina sequence.

On the basis of these paleo-hydrographic and stratigraphic considerations, the first relative dating of the cycle of conclusive sedimentations of the riverbed aggradations (to which reference should be made for the occlusion of the Saline-Cona branch), should be related to the palaeohydrological transformations attested in the High-Middle Polesine area with a trigger starting from a moment of several centuries after the occurrence of the cool/wet Lössen Oscillation (whose excursus is dated between the XVII and XVI centuries B.C.). This moment could therefore be related to the increase in the discharge of the Po di Adria 1, following the confluence of the new Po diversion (called Po di Poggio Rusco-Dragoncello-Sermide) in the previous drainage network formed by the Po river outcome of the Lössen wet fluctuation. Therefore, the layers of increase in peat horizons (previously described and sampled at Frattesina) could be related to increases in groundwater levels post-dated by the activation of this more recent raised riverbed channel (see Fig. 28).

### **2.4. The connections between the Po di Adria and the Adige river delta branches within the depositional complexes of the ancient Polesine delta coastal sectors.**

For the deltaic area pertaining to the ancient Po di Adria and included in the contemporaneous Veneto Region (Province of Rovigo), there are very few detailed information on the position of the specific coastal features (coastlines) connected to the ancient outlets of the southern branch of the Po di Adria (Fig. 23c; VEGGIANI 1972). On the other hand, only semi-detailed cartographic elements published in the literature of the last decades are available in more recent small-scale maps, relating to sandy strips of ancient shorelines (mainly beach-ridges sets) and /or dunes (back-barriers wind dunes) relative to the Bronze Age (VEGGIANI 1972 and 1974, FAVERO, SERANDREI BARBERO 1978, BONDESAN, MENEGHEL 2004; BONDESAN *et alii* 2008).

In my research I will refer mainly to documentation relating to the coastlines of the southern sector of the Venice lagoon, coastlines resulting of progradations fed by the sediment inputs transported by the Po and Adige rivers to the south, and Bacchiglione and Brenta rivers to the north (Fig. 30a). In these coastal areas the dates relating to the oldest sandy ridges buried under the lagoonal deposits concern the units following the line of maximum sea Holocene transgression (of Atlantic age: 6000-5000 B.P.: RIZZETTO *et alii* 2003): for this outcropping there are recorded segments of estuaries outlets developed after the drowning of floodplain "valleys" during the mid-Holocene transgression (see deposition of Unit H1, between 8.5 and 6 kyr B.P.: ZECCHIN *et alii* 2014) (Fig. 29a). Near the end of the transgression phase, a lagoonal area developed, and then, during the following Holocene regressive phases (high-stand marine levels), a delta system arose to the south, where a back-barrier environment persisted

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<sup>43</sup> These processes gave rise to the natural platform on which the original installations of the Frattesina site was placed.

<sup>44</sup> The peaty deposits in the area apparently began their formation following the first aggradative phases of the "pre-Lössen" fluvial channels, and kept on their growth in more recent times, till the transition to FBA1 phase.

still during the deposition of Unit H2 (Fig. 29). These first landform elements of coastal system (dune ridges and shoreface outcroppings), that correspond to the Palazzetto-Motte Cucco-S. Pietro di Cavarzere line (FAVERO, SERANDREI BARBERO 1978), are generally dated to the Early Bronze Age (4500 B.P.: RIZZETTO *et alii* 2003).

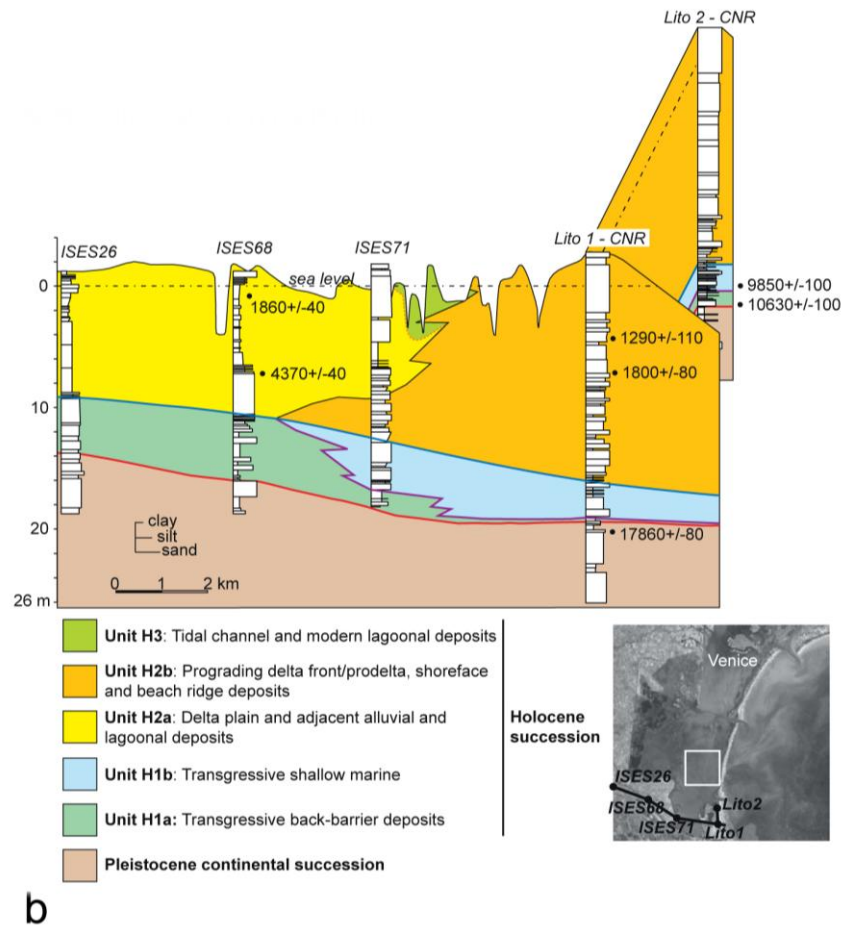
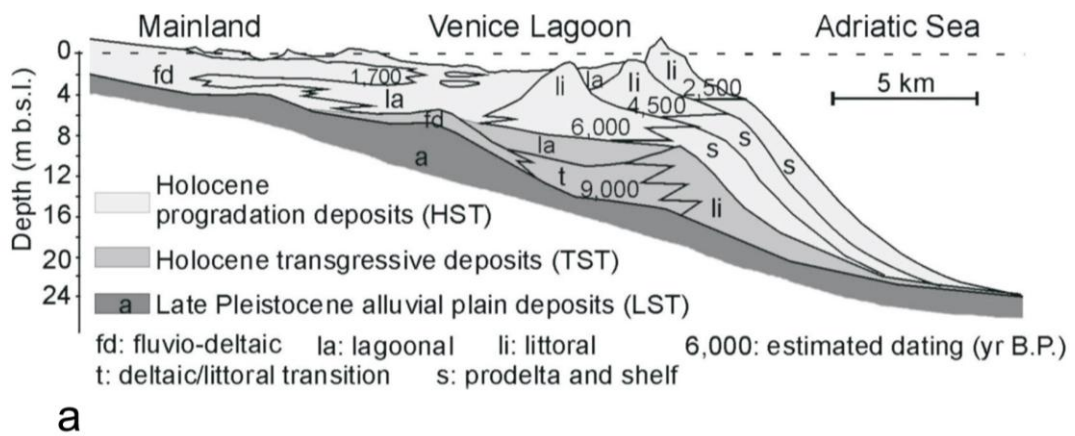


Fig. 29. Depositional environments and general stratigraphic scheme of the terminal Pleistocene and coastal Holocene age formations pertaining to the Venice lagoon. The depositional complexes relative to the late regression phases of Sub-Boreal/Sub-Atlantic transition are highlighted (in yellow and orange); (a) from BONARDI *et alii* 2006; (b) from ZECCHIN *et alii* 2014).

In this area, two separate sandy ridges progradations alignments refer to subsequent beach-line constructions:

- the first alignment, built by the confluence Po and Adige rivers (at the time joined by the "Bagnoli ridge") and dated from RBA to FBA (PIOVAN *et alii* 2012).
- the second one, more displaced towards sea, derives from the construction of the mouth of the Adige river (alone) and dated from the starting of the First Iron Age 1 (EIA1).



These two ridge-sets appear to be separated by a sharp *hyatus* (FAVERO, SERANDREI BARBERO 1978) (Fig. 30c). This erosive discontinuity in fact separates two bands of "tomboli"<sup>45</sup> whose growth sigmoidal-lines diverge clearly between them. The extensions of these two coastal apparatuses have recently been dated (as part of the research conducted by BONARDI *et alii* (2006) and extended by ZECCHIN *et alii* (2008, 2009 and 2014) (Fig. 29a), at times between the first half of II millennium B.C. the first one, and at the beginning of I millennium B.C. the second one. More specifically, comparing the dates of the Holocene beach deposits underlying those of historical age, these researches have established the detailed chronology of the H2b ridges units: 3820-3600 cal BP and 2340-1910 cal BP. In the southern Venice Lagoon area, the local coastline system corresponding to Unit H2 was interpreted as the deposits of HST (High Stationing Tract) of the Holocene Sequence Stratigraphy (ZECCHIN *et alii* 2014).

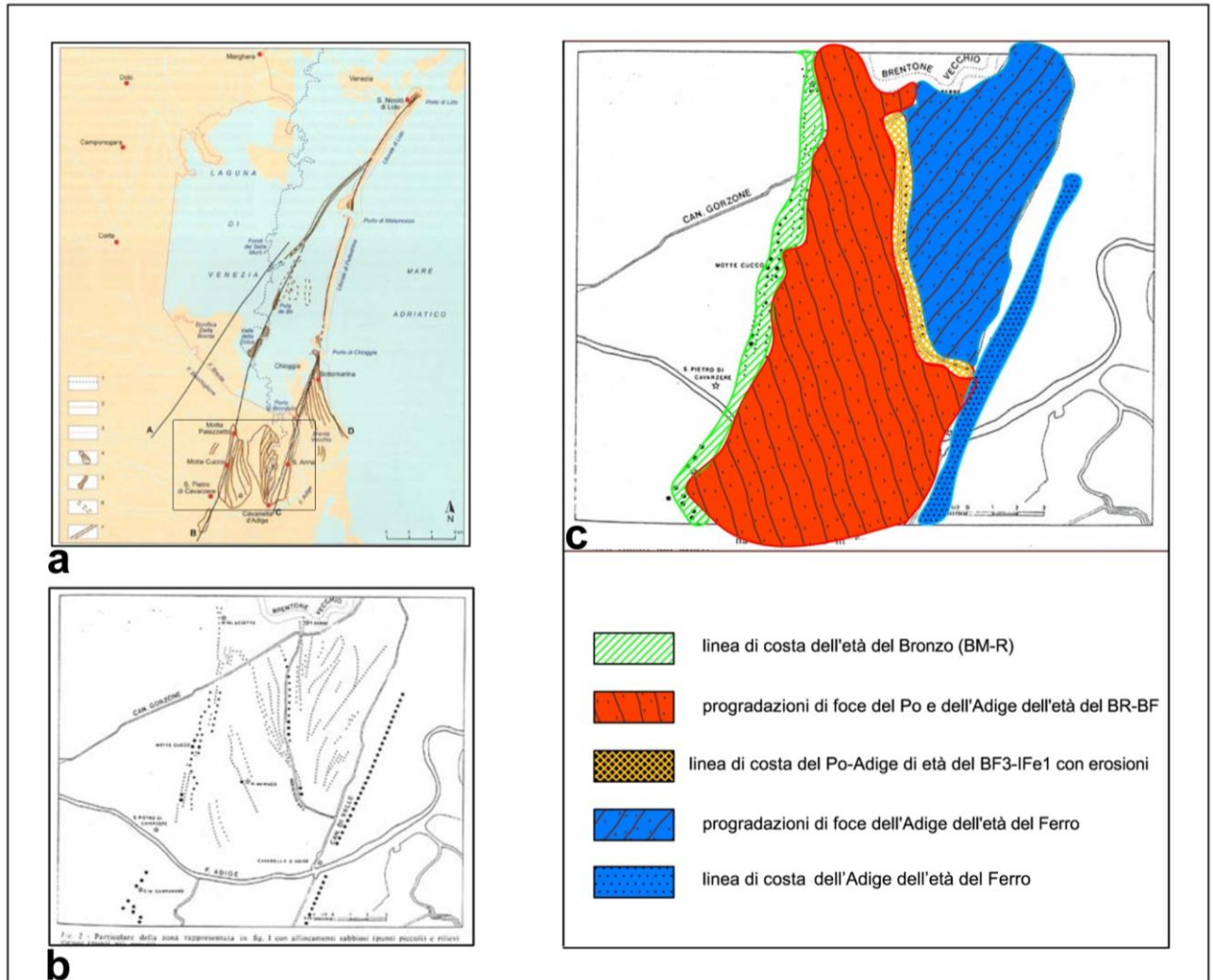
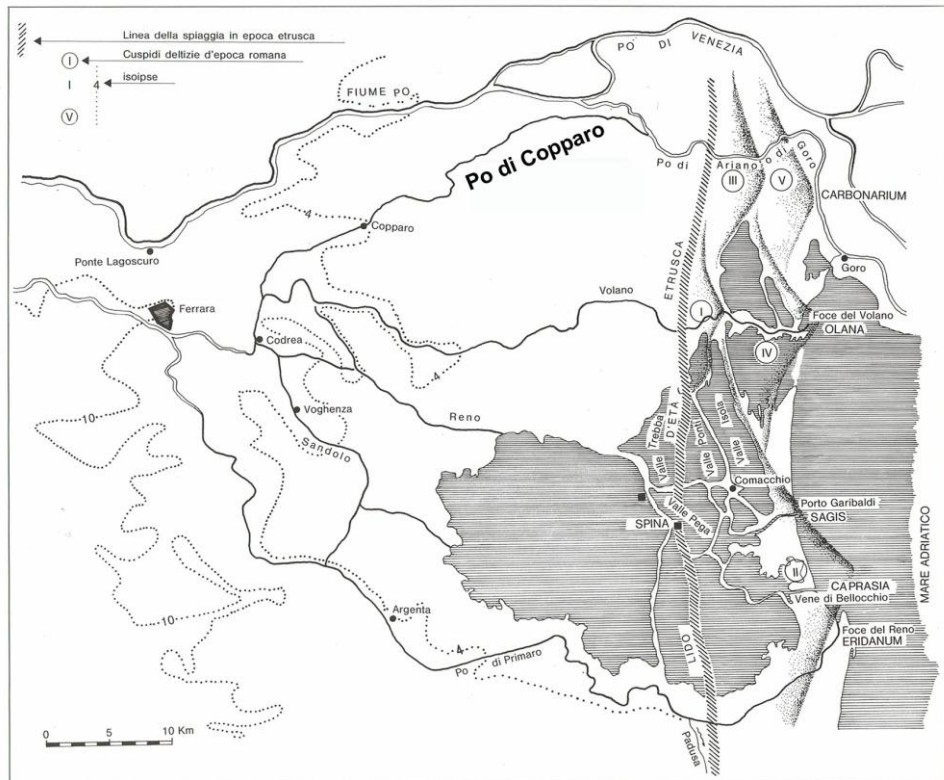


Fig. 30. Southern sector of the Venice lagoon with deltaic-coastal progradation stripes and the main stability alignments beaches of delta coastlines between the Sub-Boreal and Sub-Boreal/Sub-Atlantic phases. The subsequent coastal front alignments are indicated with different colors: from green, to yellow that are linked with the development of the M-RBA Po-Adige branch, while the blue alignment is linked with the Adige river branch alone, during the FBA till the EIA1. (modified from FAVERO, SERANDREI BARBERO 1980 and from BONDESAN, MENEGHEL 2004).

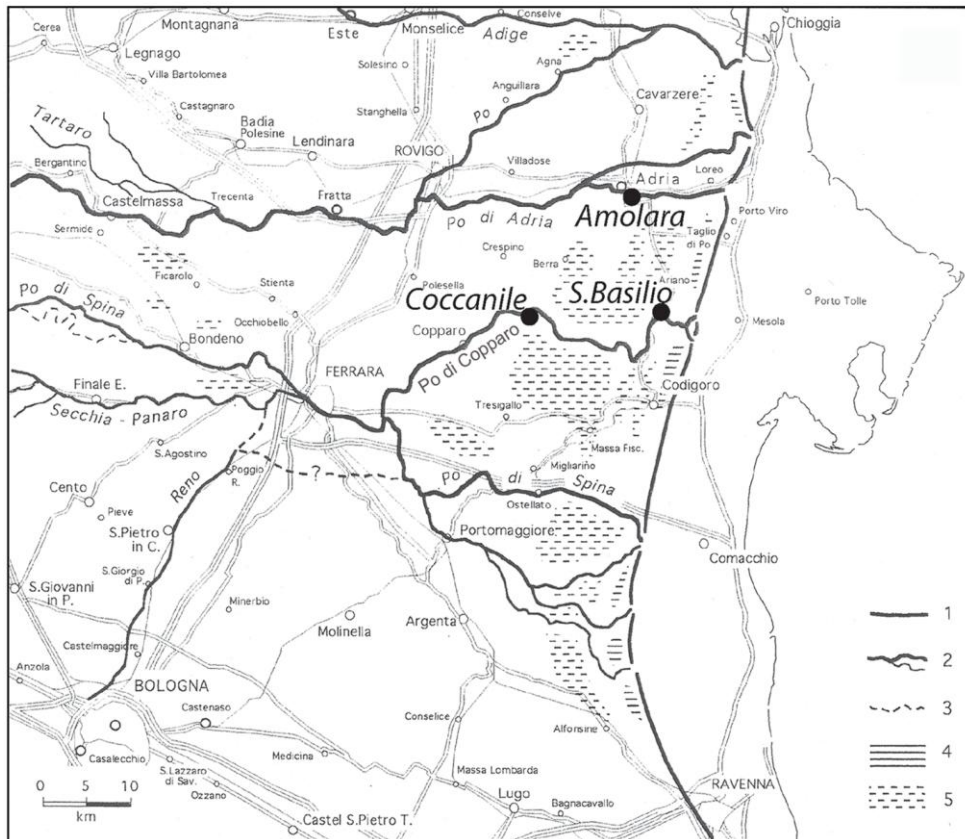
Therefore, to anticipate a first correlation between the formative episodes of the main wind dune ridges documented between southern Polesine and northern Ferrara lower delta plain and coast (see below), recovering in part the previous interpretative proposals of some authors (CIABATTI, VEGGIANI 1996), it seems plausible to propose that the activation of the Po course corresponding to the Po di Adria 1/2 should be connected with the formation of the backshore dunes named the "Canal Bianco-Tartaro" ridges (CIABATTI 1968). These dunes, cited in the literature as correspondent to the alignments that from Loreo extend southwards in Le Tombine, Le Tombe and Marozzo, formed following the activity of the Po di Ariano delta, in which the Po di Copparo was confluent between the XII

<sup>45</sup> CIABATTI (1968) distinguished the "coasts ridges", or wind origin coastal cords, from the "tomboli", or more thin bands of marine origin (equivalent to the modern beach-ridges). These formations mark the phases of the main coastal-delta growth : the shorelines coasts bodies are normally preceded inland by the major dune cordons).

and the XI cent. B.C. (PERETTO 2007). These coastal dunes would thus constitute the oldest coastal units outcropping in the territory relevant for the Po di Adria delta in the ancient Polesine (Fig. 31a).



**a**



**b**

Fig. 31. a) the paleohydrography of the Po di Ariano with the confluence of the Po di Copparo, active between the FBA and EIA1 (from ORTOLANI, ALFIERI 1965 in UGGERI 2016-2017). b) paleogeographic map relative to the primitive paths of the Po di Copparo (to the north) and of Po di Spina (to the south). The major coastal complexes along the Po delta coasts, during the RBA2 and the EIA1, are located between the Polesine and Ferrara nord sectors. Noteworthy is the location of the Coccanile di Copparo (Cà Spadolino site), from which a significant change in the paleohydrographic regime of the Po di Copparo river, dated between the RBA and the FBA emerged (modified from BALISTA *et alii* 2017 and BONDESAN 2001).

### 3. THE PO DI FERRARA BRANCHES AND THE CORRELATIONS WITH THE DEPOSITIONAL UNITS OF FERRARA DELTAIC-COASTAL SYSTEMS.

Further south of the Polesine sector, in the coastal area of the Po delta today belonging to the Emilia region (Ferrara Province), have been identified, as a result of recent geological researches (BONDESAN M. 2001; AMOROSI, MILLI 2001; STEFANI, VINCENZI 2005; AMOROSI *et alii* 2003, 2005, 2008a, 2017; Geological Sheets CARG 1: 50.000 223-Ravenna, 204-Portomaggiore, 205-Comacchio, 187-Codigoro, ed. 2009), two ancient distributary river paths: one located north-west of Codigoro and the other to the south-west of Comacchio. Both are relative to paleo-hydrographic networks that are set in the area at a time later than the end of the Middle Holocene transgression (5.2 cal kyrs B.P.: AMOROSI *et alii* 2017). To the first path should be connected the paleo-hydrography constituted by the ancient courses of the Po di Copparo and its branches that joined, during RBA, the Po di Ariano (ALFIERI, ORTOLANI 1951) (Fig. 30 a). On the Po di Copparo paleoridge has been attested recently, near Cà Spadolino di Coccanile (BALISTA *et alii* 2017), a situation of very sinuous meanders, modified from a discharge reactivation that caused the formations of cut-off channels, occurred between two dates  $^{14}\text{C}$  of 3270 +/-40 cal BP and 3010 +/-40 cal BP (RBA-FBA) (Fig. 30b).

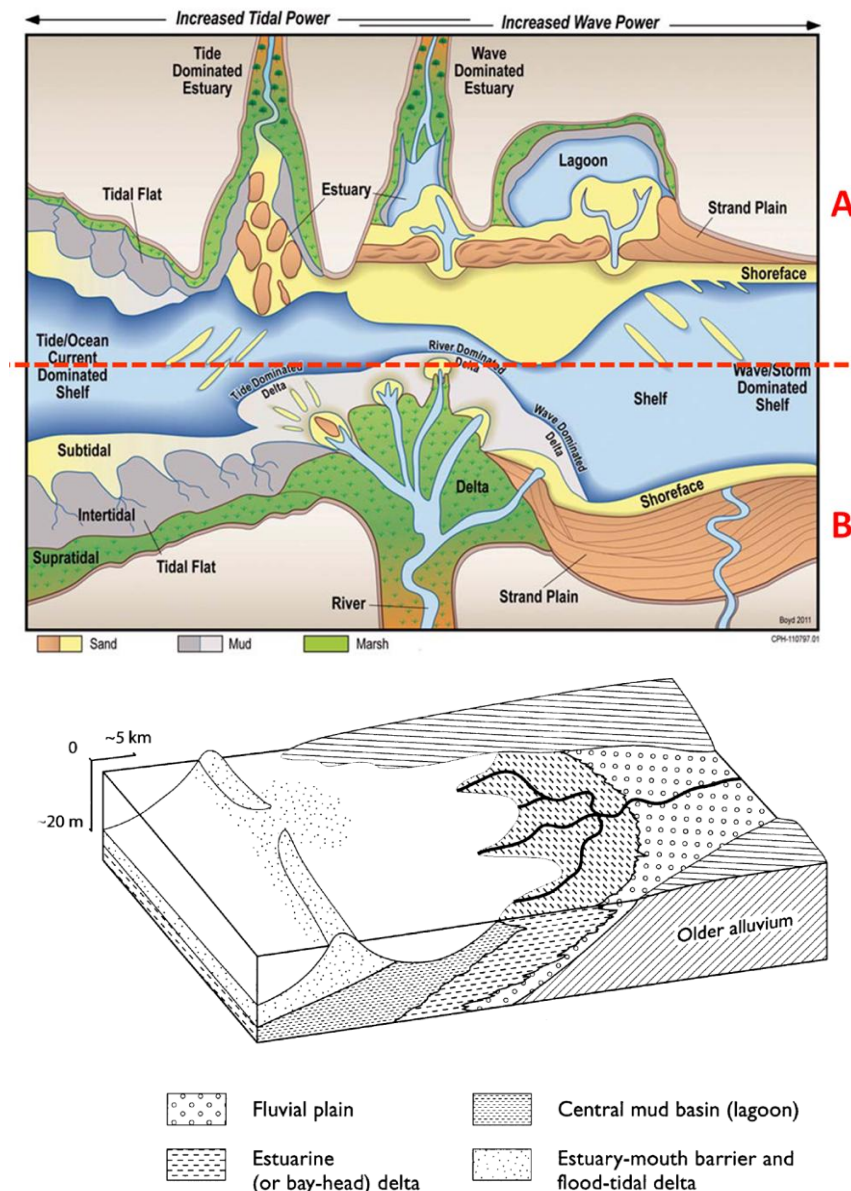


Fig. 31. a) Schematic cartoons for estuaries with outlets dominated by waves known as “wave-dominated delta” (A) and deltas with outlets dominated by rivers as “river-dominated delta” (B). The depositional sub-environments of the estuaries (barrier lagoons and tidal plains of open coasts) are typical of transgressive coastal environments (sector A). The delta sub-environments characterized by strandplains, sandy-ridge sets and tidal flats are typical of regressive coastal environments (sector B) (modified from BOYD *et alii* 1992 and PLINT, JAMES, DALRIMPLE 2010).

b) Lagoon bay-head model, with a river delta that flows into the lagoon enclosed by sea barrier-island: a model that reflects the situation in which the ancient Po di Spina flowed in the Mezzano Valley-lagoon during the Iron Age.



Starting from this date, the formation of a series of coastal deposits - alignments of litoral shorelines and wind back-shore dunes- preceded by areas of backwater lagoons , began during the early regressive phases of the Holocene high-positioning sea level (Fig. 31). These bodies were displaced in distinct coastal sections, gradually displaced towards the sea and dated, for the older outcropping, between 4500 and 3500 cal. BP (AMOROSI *et alii* 2017), therefore referable, in terms of archaeological chronology, to a period of time between the Late Copper Age and the Early-Middle Bronze Age (Fig. 32). Then follows a second belt of alignments of coastal "tomboli", moved further towards the sea, whose construction is dated among 3500 and 2700 cal. BP (STEFANI, VINCENZI 2005): they include, within them, some coastal units probably deposited, as archaeological chronology, between RBA and the FBA (at the time of the transformation of the Po di Adria 1 into Po di Adria 1/2 by confluence of the Po di Poggio Rusco in the Po di Adria 1). The chronology of these coastal formations is corroborated not only by their state of relative topographical "submergence" (BONDESAN, BUCCI 1970-71), but especially for their almost direct stratigraphical position, strictly underlying the remains of a pluristratified site that returned materials *in situ* from XI to VII cent. B.C. (Podere Alberi-Valle del Mezzano: CATTANI, BOCCUCCIA 2018).

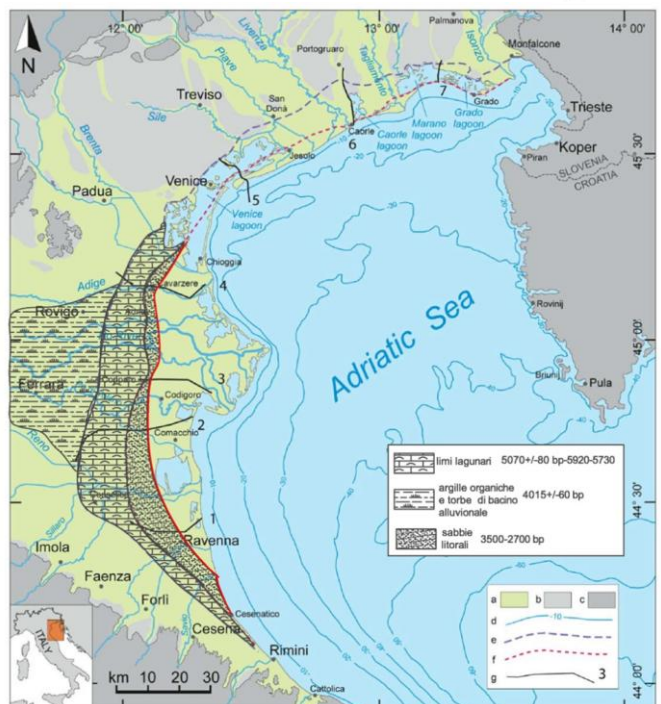
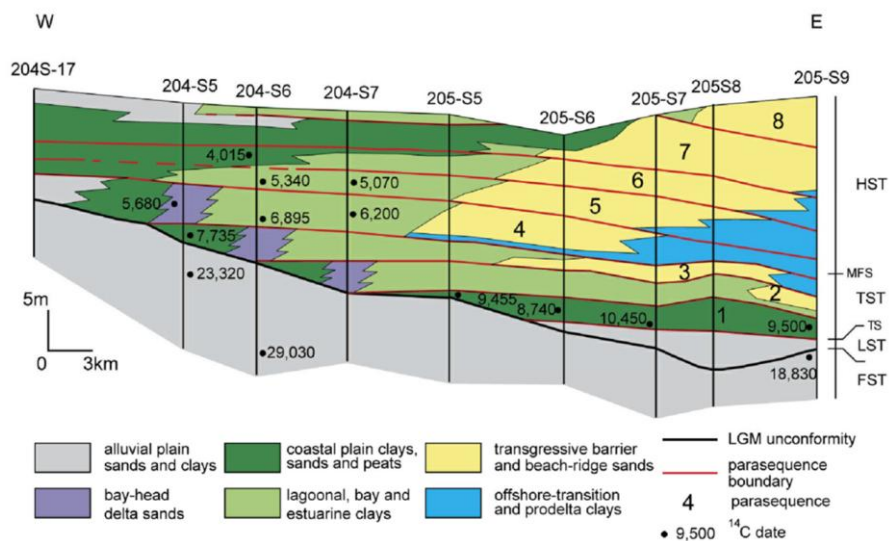


Fig. 32a, b. Fig. 32(a) Depositional complexes of the Holocene transgressive-regressive cycles, recorded along the Polesine and Ferrara coastal areas. In the first moments of the transgressive cycle the fluvial channels are characterized by estuary mouths that flow into wide lagoons barred at sea front by sandy *tomboli*. Then, there is the gradual prevalence of rivers progradation, whose contributions exceed the positive oscillations of marine levels. These processes cause the formation of beach ridge sets connected to cusped delta mouth outlets (from AMOROSI *et alii* 2005 and from BONDESAN *et alii* 1999). Fig. 32(b) Model of the main depositional facies, that formed in the back of the maximum Holocene marine transgression, based on the researches carried out in the buried delta plain of the Po river. Legend: littoral sands; lagoonal sits-sands; and organic clays and peats of brackish basins (base drawn from AMOROSI *et alii* 2008a).

Regarding to the geomorphological history of this second and more recent coastal depositional complex, it should be noted that it presents, on the sea fronts, distinct morphologies reshaped by deep erosion surfaces (STEFANI et alii 2018), ascribed to processes of energetic meteo/marine reworkings caused by coastal storms due to the intensification of winds and currents along the coast. The modifications caused by these strong winds that in those moments impacted the coast<sup>46</sup>, caused the formation of very large and elevated coastal dunes: the dunes of Loreo, S. Basilio di Ariano Polesine and Italba-Massenzatica, whose formation is referred to a date very close to 900 B.C. (BONDESAN et alii 1999)<sup>47</sup>. These remarkable coastal-aeolian dune features are characterized by relatively coarser grain sizes than the previous ones, that is believed to have been determined by the establishment of a considerable changes in the coastal meteo-marine weather regimes and in the direction-intensity of winds and longshore currents (increased transport capacity of the down-drift currents)<sup>48</sup> (Fig. 33).

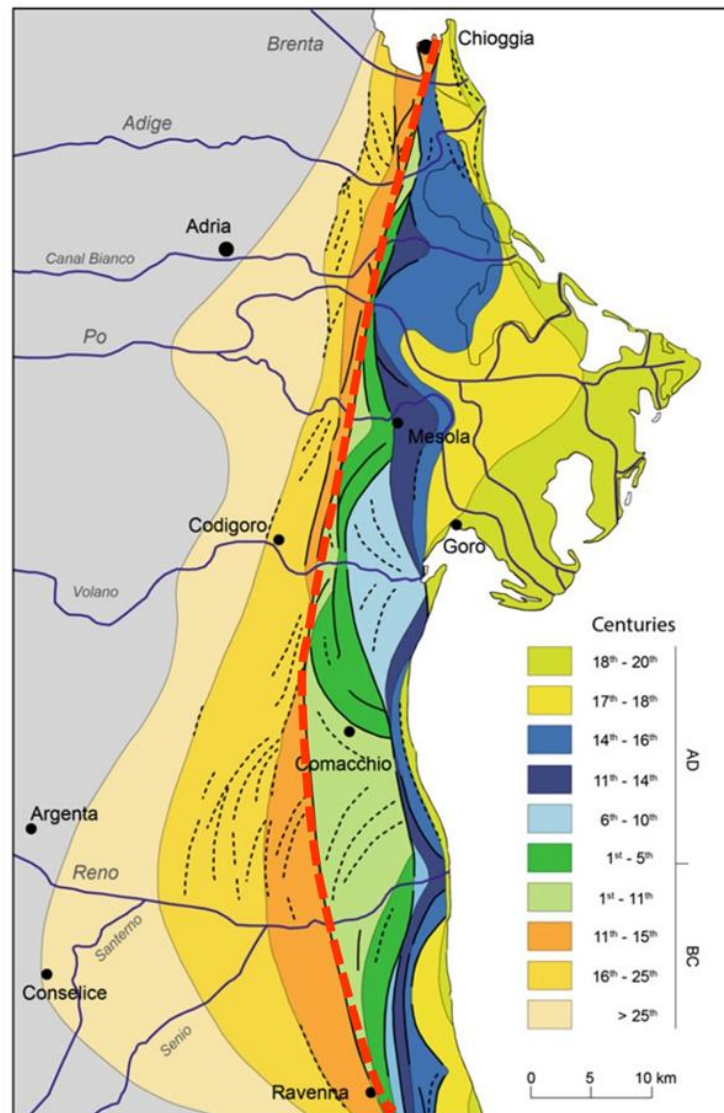


Fig. 33. The extensive erosion surface originated by the cold and windy Göschenen 1 Oscillation during the Sub-Boreal-Sub-Atlantic transition (900-850 B.C.) (modified from STEFANI, VINCENZI 2005). During this stage occurred the closure of the barrier islands and started a vigorous over-flooding of the Po di Adria, which changed from the Po di Adria 1/2 to the Po di Adria 2. These processes are at the base of the floods that involved large sections of the inland territories of High-Middle Polesine, including fluvial sections nearby the sites of Frattesina and Villamarzana.

<sup>46</sup> The deep transformations caused by the aforementioned weather-climatic phenomena have been deduced from changes observed on the directions of the prevailing paleocurrents: they form ridges aligned according to directions north50°west, caused by the prevailing winds from north-east (Bora, along the coast) and from south-east (Scirocco) (STEFANI, VINCENZI 2005).

<sup>47</sup> See, for the age of formation of the S. Basilio dunes, the *terminus ante quem* made up of the archaic Paleo-venetian settlement remains *in situ*, which returned pottery of the second half of the VI cent. B.C. (DE MIN, IACOPOZZI 1986).

<sup>48</sup> So, I believe that the erosion surface aforementioned would mark the transition from estuary to delta complexes in the coastal morphology of the Po delta.

The two distinct processes, the formation of new coastal deposits and the erosion of the previous coastlines, should be differentiated as their origin:

the first would be the result of a significant increase in the volume of the Po river discharges, which during these phases (from 3500 to 2700 cal BP) were more and more concentrated towards the new central branches of the Po (branch of the Po di Adria 1/2 and branch of the Po di Copparo). This first series of events would have ended with the triggering episode of the Sermide Flood, which determined the diversion of the Po di Adria 2 flows on the new route of the Po di Ferrara towards the branch of Po di Spina. This new flows, during the course of Early Iron Age, fed the formation of new alignments of dunes and shorelines along the Ferrara coasts : the dunes on which were later located the Spina necropolis of Valle Trebba and Pega of VI-IV century B.C. (Fig. 34-a).

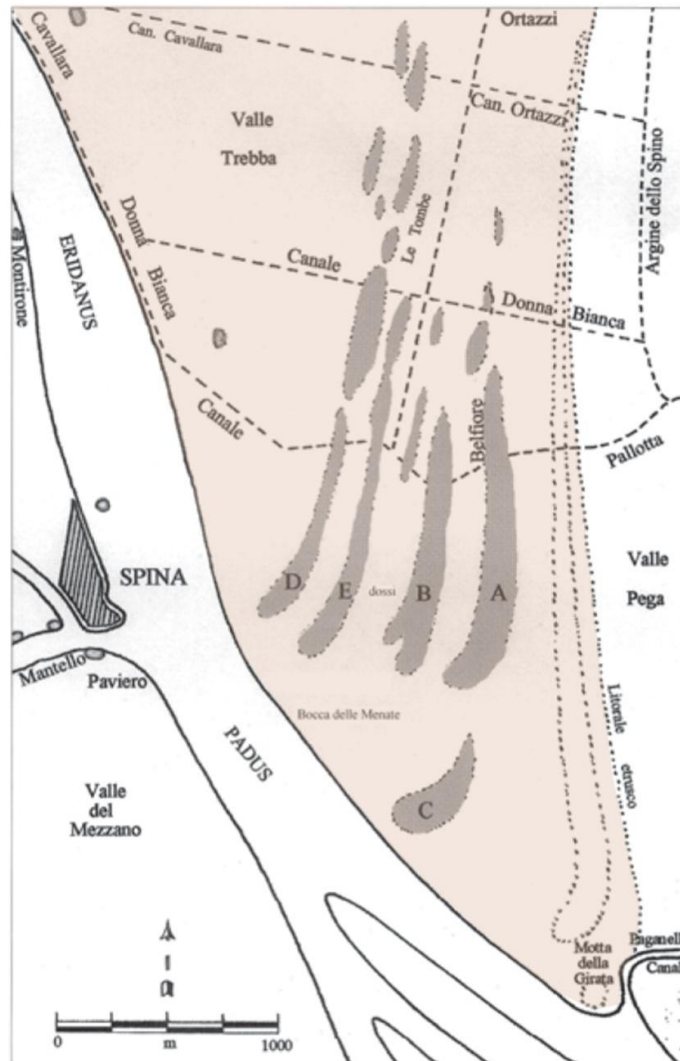


Fig. 34. The Spina necropolis map and the coastal depositional complexes of Valle Trebba and Valle Pega of pre-Etruscan age: main wind ridges (back-shore dunes) highlighted in gray and those of the last sea-front alignments marked by dots (from UGGERI 2006).

This more recent coastal alignment belts, with associated back-beach ridges, should therefore be attributed to the coastal systems that were formed following further phases of progradation of the southern distributary channels at the mouth of Po di Spina, fed by the the discharge of Padoa-Eridano of pre-protolithic age (BONDESAN 2001; VEGGIANI 1974). The construction of these new cusped deltaic ridge bundles should be ascribed to the occurrence of two successive cycles of progradation of the Po delta-coastal fronts, dating from the Middle to Recent Iron Age. These coastal apparatuses could thus correspond, at least in part, to the bundles of "Greek" and "Etruscan" dune cordons proposed by Ciabatti (1968). Finally, a phase of further construction of the Po deltaic apparatuses should be attributed to a reactivation of the Po di Spina river outlets, connected to the two distinct cycles of river progradations included between the pre-Roman age (III-II cent. B.C.: GIACOMELLI *et alii* 2018) and the Ancient Medieval Age (VI-VII cent. A.D.) (BALISTA, BERTI 2017, 2018 *in press*) (Fig. 35).



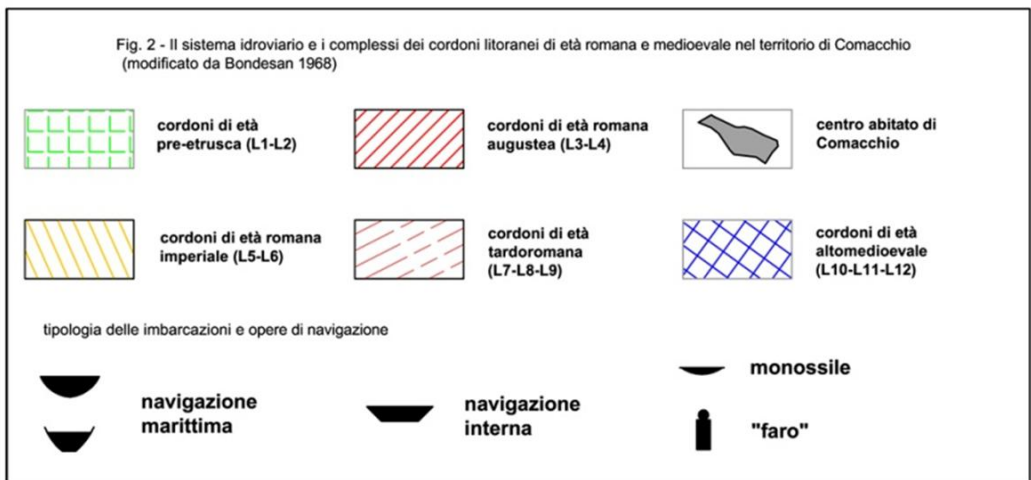
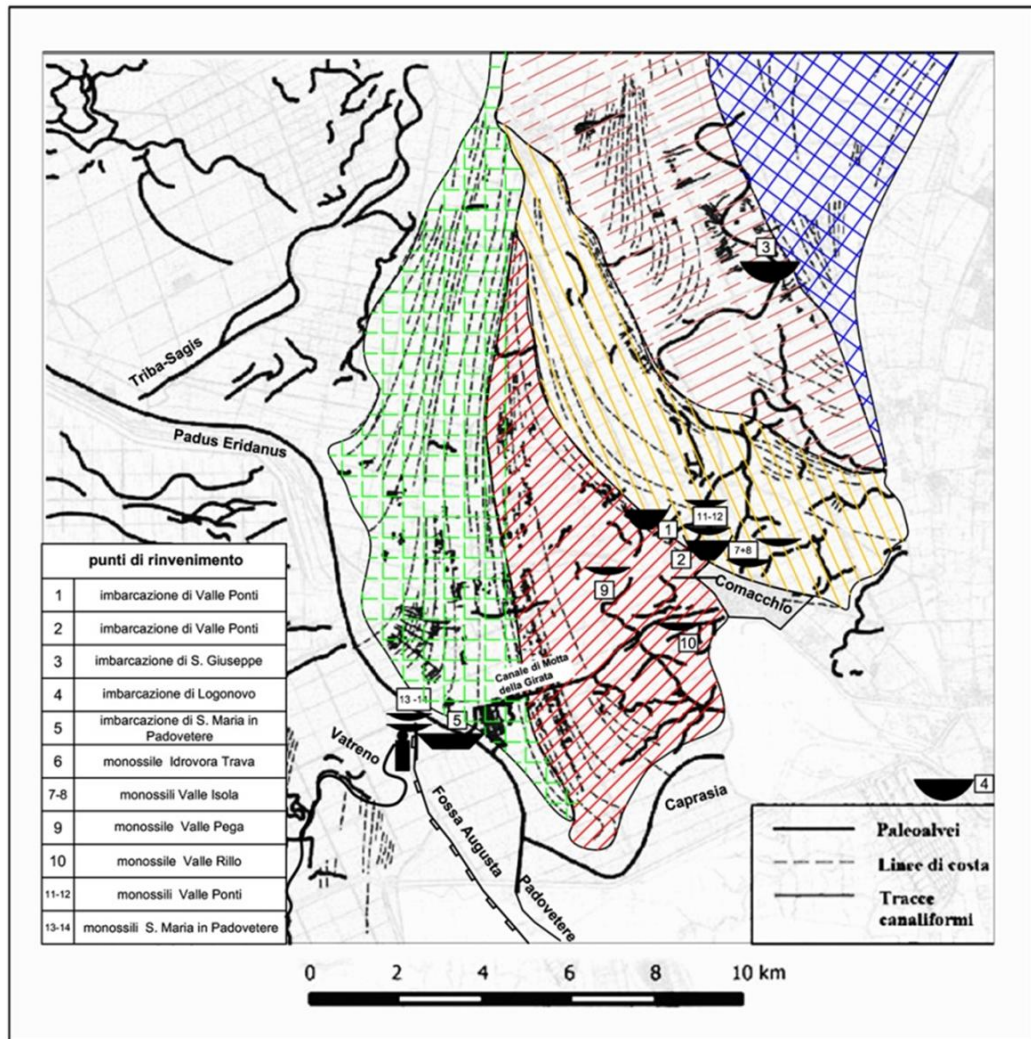


Fig. 35. Chronological and spatial definition of the main groups of coastal ridge-bundles in the territory of Comacchio (Ferrara): in green: pre-Etruscan age (pre-550 B.C.); in red: since Hellenistic age (III century B.C.) till I cent. B.C.; in yellow: Roman beach stripes (I-II A.D.); in orange (V A.D.); in blue: medieval age.

Finally, the second set of (erosional) processes mentioned above it would be conclusively to lay in correspondence of a particular event, mainly erosive, dated to about 2700 cal. BP, that would be attributed to the occurrence of a very anomalous sequence of episodes, of almost certainly climatic origin (in the sub-arid/cold trend). It coincided with the formation of higher coastal dunes favored by an intensification of the winds of Bora and Scirocco, whose power would have increased with the occurrence of a cold-dry climate pulse. The changing directions of this new prevailing winds caused the deep erosion of the shoreline alignments previously deposited.

## 4. DISCUSSION.

### 4.1. The Po river-delta and coastal depositional environments evolution in Polesine and Ferrara areas linked mainly to the climatic fluctuations of the late Sub-Boreal to Sub-Atlantic transition.

As noted before, it should now be underlined that the first stages of expansion of silt-sandy alluvial covers, generated by an increase in sediment discharge derived by remobilization of soil matrixes (caused by extended deforestation/clearance activities (CREMASCHI 2017), began in an evident way from the second half of Sub-Boreal Age. The formation of crevasse splay and flood channels that flow out from the natural embankments, generated by reactivated rivers, resulted in significant transformations in the depositional environments of the Po river delta. The first important remodeling of the fluvial belts' topography and the primitive fluvio-deltaic distributaries patterns' transformation seem to be the outcomes of the unfolding of the Lössen Fluctuation (EBA-MBA). These processes led to noticeable modifications in the previous predominant (pre-EBA) fluvio-lacustrine and stagno-alluvial environments in the reference areas (Fig. 32b).

To the sides of these new fluvial belts and of the distributary-deltaic branches going towards the coast, the fluvio-lacustrine and marshy basins of the previous environments began to be replenished with clastic (minerogenic) matrixes. Starting from these episodes, we find the first correlative correspondences between the river depositional complexes and the coastal-marine deposits referable to the ancient phases of "high stationing" of the marine levels (highstand of Holocene regressive cycle phases). These phases, in the Ferrara deltaic and coastal area are related to the intermediate episodes of construction of the "parasequence<sup>49</sup> 5", a depositional complex dated between 5.2 and 2.8 cal. ky BP (AMOROSI *et alii* 2017 and Fig. 32a).

The fluvio-deltaic basins mentioned above were therefore, in the glimpses of the Sub-Boreal period, subjected to episodes of shoaling (reduction of the water levels) more and more recurrent and extensive. On those surfaces, quickly revegetated, there were transitions from peat of hygrophilous woodland in the central areas still flooded, to hydromorphic entisols on the overflow stripes that formed on the river banks to the margin of flood-basins.

Finally, the faster construction of ever wider and more marked natural banks (interspersed with ever more numerous crevasse splays due to fluctuations in flow rates) and the greater sedimentary load of rivers channeled to the sea, completed the channels pattern transformation from anastomosing to meandering. These processes, thanks to the availability of more extensive areas of land suitable for agriculture and livestock breeding, opened the possibility of setting up new sites on the margins of alluvial plains, close to the river or distributary courses (see ARNOLDUSSEN 2007 and PENNINGTON *et alii* 2016).

### 4.1. A convincing relation between sea-weather coastal processes, paleoclimatic oscillations and related geomorphological and hydrographical transformations.

As regards to the particular phase of deep erosive changes suffered by the coastlines of the Po delta front between the archaeological phases FBA3 and EIA1 (see *above*), it should be noted that it has been possible to find some examples of formation processes of coastal complexes quite similar to those that stroke the high-Adriatic coastal sector in a date very close to the beginning of early Iron Age. In the Spanish south-east coast, in fact, in correspondence to coastal ridges complexes detected therein, have been recorded some changes in the orientation

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<sup>49</sup> The "Parasequences" in the Adriatic coastal environments consist of depositional complexes of a pluri-metric thickness formed by units derived from the progradations of river deposits, to which correspond towards sea coastal deposits derived from currents and waves reworking. The depositional processes within the parasequences are controlled by the "accommodation space/sedimentation rate" ratio: a decrease of the first is associated with an increase in the buildup of sediment poured into the sea by the rivers of the second. To mainland, these deposits, normally initiating with coastal components (mouth bars, beaches fronts, wind dunes, etc.), generally show transitions from lagoon to brackish facies, which in turn interdigitate with organic-freshwater deposits, with peaty-marshes increasing in the subsided basins that form on the sides of the river belts/distributary channels that flow into the sea bays/lagoons.

The parasequences begin with the arrival of new sediments on the coastal fronts, where they develop at the base with pro-deltaic facies, more coastal upward, then evolve towards the surface to facies of increasingly shallow environments, that can reach the stage of partial emergence. These surfaces, with traits that can remain in sub-aerial exposure for more or less long periods, can be erased by casual erosion processes, from the insertion in the area of both fluvial and tidal channels, and/or buried on the margins by floodings related to successive transgressive cycles (COE *et alii* 2003). Therefore, the persistence of surfaces suitable for the stable settlement has a higher probability of survival in the coastal than in the paralic/lagoonal ones (salt-marshes), or in the transitional strips that form on the edges of deltaic distributary ridges.

On the Emilia-Romagna coasts the entire depositional thickness of the Holocene age was subdivided into 8 parasequences (AMOROSI *et alii* 2017). Among these the first 3 refer to the TST (Transgressive System Tract), sequences of transgression to land of coastal-marine deposits connected to the rapid sea post-glacial rise; the last 5 parasequences include the Highstand System Tract (HST), formed by progradational deposits, that mark the advancement toward the sea of the ancient coastlines, caused by the slowdown in the growth rates of marine levels and the prevalence of rivers sedimentations on coastal-marine accommodation space.

(strike) of the units of the beach ridges (unit H4). These were due to remodeling by winds and sea currents, that changed notably the sliding prevailing directions with respect to the previous one (GOY *et alii* 2003)<sup>50</sup>. In these places (Gulf of Almeria), because of these energetic processes of coastal remodeling, significant erosion activities on the cusped beaches of the previous phases occurred and concluded with a realignment of the coastal ridges according to prevailing east-northeast directions, which culminating with the formation of new beach ridges dated 2700-2750 cal. BP. According to some scholars (SABATIER *et alii* 2012), such events would be related to episodes of arid-cold climatic deterioration recorded simultaneously in the North Atlantic regions (BOND *et alii* 2001). I propose that the age of the deep geomorphological transformations recorded by the Spanish coastal complexes would be the same for the marked modifications in the alignments of the high-Adriatic coast of the Po river delta. This fact leads me to assume that the aforementioned processes of coastal progradation first, and subsequent erosion then, are due to the same weather-climatic conditions established almost simultaneously in the Mediterranean areas of north-west and north-east coasts.

On the basis of further parallels, relative to meteo-climatic conditions recorded in the area included between sectors to the north and south of the Alps, corresponding to the chronological excursion shown here (SPERANZA *et alii* 2000; MAGNY 2004; MAGNY *et alii* 2004, 2009, 2012; BLAAUW *et alii* 2004; ROBERTS *et alii* 2011; MERCURI *et alii* 2012), it is ultimately proposed as this "violent paleo-climatic phase" (STEFANI, FONTANA 2007), may reliably have occurred at the onset of the arid-cold Göschenen I Oscillation. This oscillation does correspond, at a pan-European level, to the transition phase occurred between Sub-Boreal and Sub-Atlantic periods (VAN GEEL *et alii* 1996, ZOLITSCHKA *et alii* 2003)<sup>51</sup>. Along this path, it should be then noted that the coastal progradation phase, marked by the formation of the relatively imposing coastal dune alignments mentioned above (e.g. complex of beach coastlines and related strips of aeolian dunes of S. Basilio-Massenzatica-Italba)(Fig. 33), *per se* should be ascribed to the erosive/depositional results (aggradation/progradation of coastal deposits and successive erosion) linked to the same phase of strong instability that marked the end of the most stable and prolonged continental-dry phase (CREMASCHI *et alii* 2016), which favored the unfolding of the archaeological phase of the FBA sites in the SVL and H-MP areas.

#### 4.2- Paleo-demography and climate change in Po di Adria fluvio-deltaic sector.

Recent studies based on a "SCPD" approach (*Summed Calibrated Probability Distribution*: CAPUZZO *et alii* 2018), have allowed to compile a curve of the Bronze Age human population (see demographic fluctuations in Fig. 21a) for the Po Valley deduced from 134 <sup>14</sup>C dates sampled from sites listed in the literature. I compared this curve with some paleoenvironmental reconstruction curves extended between the MBA and the FBA (parameters considered:  $\delta$  summer rainfall,  $\delta$  summer temperatures,  $\delta$  fluctuations of lake levels). Based on these evaluations we can observe a significant correlation between the two major population peaks (MBA1 and RBA2- advanced RBA2) and the high lake levels of the two lakes of Ledro and Accesa (Fig. 21d), together with the moderate summer temperatures and the increased rainfall (Fig. 21 b-c). A curve of the population phases (number of sites for chrono-typological phases) was developed by Dalla Longa (Doctoral thesis, 2015, unpublished) for the Verona province<sup>52</sup> (see Fig. 35e-baseline graph). The same type of computation extended by her, to the province of Rovigo (after a critical period of almost de-population in correspondence with the phases EBA-MBA<sup>53</sup>) has returned a secondary peak of very evident population increase, between the RBA2 and the advanced RBA2, followed by a evident decrease in FBA1-2, and then remain at an intermediate level between FBA1-2 and FBA3-EIA1 (Fig. 36).

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<sup>50</sup> The predominant east-facing components, that replace the previous currents with components from south-west.

<sup>51</sup> After the energetic erosive phase of meteo-climatic origin above, the formation of successive coastal belts, marked by stripes of cordons with morphology from lobate to cuspidate, continues throughout the first Iron Age and is accompanied by an exclusive return of the Po river routes in the central-southern delta area, in correspondence with the Ferrara sector of the Emilia coast (first defined as the path of the Po di Spina: CORREGGIARI *et alii* 2005a and 2005b; CIABATTI 1968; BONDESAN, FAVERO, VIGNALS 1995).

<sup>52</sup> Similar results were achieved in the pioneering research aimed at the analysis of population dynamics of in the Verona plain, led by ATZORI *et alii* (2005), but that for the purposes of this writing appears limited not only to the interval considered (EBA-RBA), but above all due to the absence of connections with the neighboring riparian bands of the ancient Po di Adria, an essential perspective for these researches, emerged only ten years later (BALISTA 2017).

<sup>53</sup> Most probably because of the extensive presence of fluvio-lacustrine and peaty-palustrine basins very little "attractive" for the settlement of the time (see above).



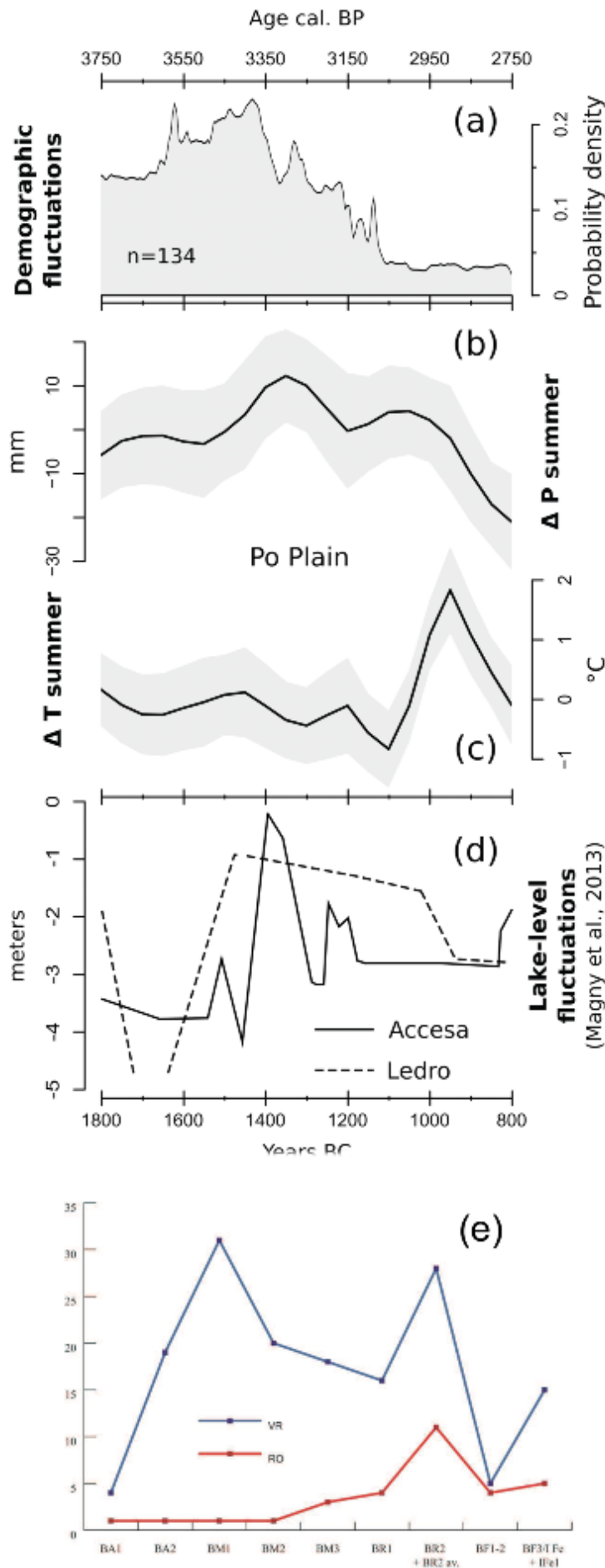


Fig. 36. Bronze Age demographic dynamics diagrams for the Southern Europe (Po Plain) and their response to regional climate modifications: a)  $\Delta$  cal. date and number of sites; b)  $\Delta$  summer precipitation; c)  $\Delta$  summer temperature (in Celsius degree); d)  $\Delta$  lake fluctuations; e)  $\Delta$  number of sites per phase for the territories of the SVL (blue) and HMP (red) (from CAPUZZO *et alii* 2018 and from DALLA LONGA 2015).

## 5. TOWARDS A GEOARCHAEOLOGICAL EVALUATION OF THE RELATIONSHIPS BETWEEN THE MAIN SETTLEMENT PHASES OF THE EBA-MBA AND THE RBA-FBA SITES IN THE CENTRAL-EASTERN PO PLAIN AND THE PALEO-HYDROGRAPHIC CHANGES RECORDED IN THE DELTAIC-COASTAL TERRITORIES CROSSED BY THE PO DI ADRIA ON THE ADRIATIC COAST.

Based on the results of the aforementioned geological, archaeological and geoarchaeological researches, an attempt was made to establish a first series of chrono-stratigraphic correlations just among the units of some archaeological complexes and the connected groups of geomorphological units connoted by the inclusion of geoarchaeological contexts formed between the late EBA and the first EIA1.

These have been analyzed in the light of the relationships, but for still not completely explored, between the random transformations fixed by the branches of the ancient Po River delta-coastal complexes and the co-evolution of the settlement locations tied to the anthropic use of the surrounding territories. In this dynamic system the main connection element is represented by the positioning returned by the traces of the ancient Po di Adria river belt; of obligation, these relationships were extended to its distributary branches in the deltaic-coastal environment.

For this purpose, the researches undertaken have been distinguished firstly by the chronology of the identified phenomena, considering both the scales of development and the different degree of resolution. There were considered different approach scales for the two individual disciplines: the geological one is based on the <sup>14</sup>C analysis, focused to date "group of units" about the natural origin deposits, whilst the archaeological one paid attention to "single units" (archaeological units derived from anthropic activities). The chronologies and significance of the aforementioned "geoarchaeological complexes", that often include or are correlated with layers and/or surfaces contained in archaeological sites, has been formalized although still based on a rather limited number of absolute dated chronologies.

The overall analysis of paleo-hydrographic, paleo-environmental and geoarchaeological data collected in this way, has led to identify **five main phases** of significant paleo-hydrographic and paleo-geomorphological changes, which have affected the territories listed above during the Sub-Boreal/Sub-Atlantic transition (Fig. 37). These are formalized as follows:

-a first phase (**phase 1**) runs between the end of the late EBA and the beginnings of the MBA (1700-1600 B.C.). It corresponds to a reactivation stage of the fluvial flows of the Po di Adria, coinciding with the occurrence of Löss Oscillation, which had as consequence the formation or the re-organization of some avulsive branches of the ancient Po river (Po di Adria 1 to the north and Po dei Barchessoni to the south) and the formation of new secondary flood channels. These hydraulic reactivation phenomena caused extensive changes in the previous patterns of the Po di Adria, and even further south, on the very sinuous residual morphologies of the Po dei Barchessoni and the Po di Ferrara meanders. The flows increasing, recorded by the HMP segments of the Po di Adria, caused the diversion of route channels (crevasse channels and flood-channels) on the settlement of Canar between phase I and II (BALISTA 1998b) and the origin of new branches of temporary route channels, such as the paleochannels of Canova, Ceneselli and Campestrin di Grignano Polesine.

-a second phase (**phase 2**) is identified by a synchronous development with the unfolding of the cultural cycle of the *terramare* (CREMASCHI *et alii* 2017), which settlements are distributed over a large area of the central-eastern Po plain, only partly involving the deltaic and coastal areas of the lower Polesine<sup>54</sup>. During its development, from the MBA to the RBA (from 1600 to 1200 ca. B.C.) there is a long reduction phase of the river flows, connected with more and more sub-arid peaks towards the end of this long settlement cycle (see S. Rosa di Poviglio and Fondo Paviani dry pulses: CREMASCHI *et alii* 2006; NICOSIA 2015; DAL CORSO *et alii* 2017). There are no substantial changes on natural drainage networks recorded in this period, both in the north and south of the Po river plain. The main transformations known are of anthropic origin and are directed to the preservation of land reclaimed areas. It could be related in the first time to the danger of swamping toward the north, caused by diversion of new flood channels from the main new riverbeds: this situation required the construction of the SAM embankment (BALISTA *et alii* 2016). In a second time, during the the dry peaks, it was the deepening of water levels in pre-existing ditches and natural channels caused by the groundwater lowering, a phenomenon further increased by a by anthropic captures of lowered groundwaters within the densely colonized territories of the *terramare* settlements.

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<sup>54</sup> Both, for the extreme rarefaction of the sites, and for the high degree of alluvial burial to which the area has been subject during the progradative evolution of the Polesine delta in the late Holocene.





- the third phase (**phase 3**), takes place between the end of the RBA (RBA2: 1200-1150 B.C.) and the beginnings of the FBA (FBA1: 1150-1100 B.C.). It comes to be identified with the occurrence of numerous and extensive natural processes, which on a large scale merge the evolution of the Po plain river network with that of the deltaic and coastal areas. The main role among these events is marked by the erosive channeled floodings, caused by the full activation of the Po di Poggio Rusco-Dragoncello-Sermide and its confluence in the Po di Adria 1, that results in the Po di Adria 1/2. The same reactivation phenomena of the previous river routes are recorded at the northern emilian *terramare* of Bardellone and Pilastrì (BALISTA 2007). Furthermore, these processes are referred to: the powerful alluvial deposits that covered the Canova site; the formation of large crevasse splay of Castelmassa; the meander enlargements and the meanders cut-off of Ceneselli and Campestrin; the formation of crevasse splay that originated the basal platform of the site of Frattesina and the generalized over-flooding of the Saline-Cona branch, which diversion ended by the erosion on the Adria Amolara site. Moreover, on the coastal strips, there should be added the progradations of the new lobes of the Adige river, distinct from the Po di Adria ridge (in rapid construction in the Polesine sector to the north). Finally, in the central sector of the ancient Ferrara delta there were some diversions of Po di Copparo/ Po di Ariano branches and some construction episodes in the back-bar platforms of the perfluvial settlement of Ca' Spadolino - Coccanello, on the Po di Copparo (FE).

- the fourth phase (**phase 4**) is characterized by a development included between the two chronological boundaries of FBA 1-2 and FBA 3 (1100-900 B.C.). This phase, even though marked by a relatively long progress, does not appear to have left sizeable paleo-morphologic changes, probably because of the incisive geomorphologic setting that distinguishes it. On the section of the Po di Adria 1/2, documented in correspondence of the reconstructed transect of Frattesina<sup>55</sup>, was recorded a specific transformation in the composition of the deposits analyzed in correspondence with the upper filling units of the local river channel. First a very deep erosion process was recorded: the river bed reached the quote of -13 m under sea level and then was filled with units of medium-fine massive sand, till to topographic level of -7 m under sea level. This homogeneous evolution of the terminal channel filling of the Po di Adria 1/2 appears to be in close relationship with the balanced "graded" water flow regime, which marks the whole unfolding of this phase<sup>56</sup>, as is evidenced by the succession of the subtle and limited sequences of overflows/floodings found on the sections of the necropolis of Narde II (SALZANI 2010; DI ANASTASIO 2010)<sup>57</sup>. The limited construction deposits of delta-coastal complexes related to this phase would be correlated with these reduced and graded sequences of riverbed-fill and natural banks construction of the Po di Adria 1/2<sup>58</sup>.

- the fifth phase (**phase 5**) last since the end of the Bronze Age (FBA3: 1000-900 B.C.) to the beginning of the first Iron Age 1 (EIA1: 900-800 B.C.). It takes place at the same time as the unfolding of the oceanic/cold oscillation marked by cold-arid points of the Göschenen 1 Oscillation. This phase included the vast phenomenon of the complete avulsion of the Po di Adria, which starts with the "Sermide Flood" and ends with the formation of the new branch of the Po di Ferrara, called Po di Spina 2 (BALISTA 2013). At the same interval are to be ascribed the extensive erosion recorded on the coast lines by the complexes of the *back-shore eolian dunes* that expand between the delta of the Adige and the Po di Adria 2. This meteo-marine energetic process extended from the central sector of the Polesine delta, to reach the coastal complexes of the Po di Copparo/Po di Ariano, in northern sectors of the Ferrara Po delta.

## 6. CONCLUSIONS.

In the SVL and H-MPolesine, the two arrays of the most evident paleo-hydrographic transformations that occurred subsequently in the **phase 1** (EBA2-MBA1: XVII-XVI cent. B.C.) and in the following **phase 5** (EIA1: IX-VIII cent. B.C.), were highlighted as the result of the triggering of as many climatic fluctuations, called, in the European context, Löbber Oscillation and Göschenen I Oscillation, that occurred respectively in the second part and at the end of the Sub-Boreal continental climatic period. The first fluctuation was characterized by continental conditions with wet-cool peaks, whilst the second as oceanic with dry-cold peaks. They are both linked to an increase in precipitations and a concomitant decrease in average summer temperatures. These climatic and meteorological phenomena corresponded to a thickening of glaciers, a rise in lake levels and, at the same time, an increase in fluvial discharges,

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<sup>55</sup> Based on the results of mechanical corings carried out between the site and the northern Necropolis of Narde II (Balista in BALDO *et alii* 2018)

<sup>56</sup> As on the other hand, it is evidenced by the succession of sequences of light overflows detected on the sections of the Necropolis of Narde II (DI ANASTASIO 2010).

<sup>57</sup> Necropolis that developed on the units of the neighbouring natural banks of the great river.

<sup>58</sup> Or, maybe, the sequence was almost completely removed by erosion?

together with the greater sediment volumes displaced from the hilly-mountainous basins towards the Po river floodplain. Finally, together with the extension and the growth of natural river embankments and the raising of riverbeds, accompanied by more widespread processes of overflowing is recorded at first a rapid groundwater growth, concluded then by a slower recovery of the previous lower groundwater levels. These processes caused the transition of the surrounding fluvio-lacustrine environments that still prevailed in river basins of lower floodplain and upper delta plain, to fluvio-palustrine environments<sup>59</sup>; lastly, they changed into extensive covers of sands, silty-sands and silty-clays in the lower alluvial and delta plain.

The **phase 2** portrayed above coincided with the spread of settlements and diffusion of *terramare* sites, promoted by a paleo-hydrographic "standstill" during the unfolding of a prolonged continental climate range. Towards the end of phase 2 some aridity peaks caused a groundwater lowering both within the spring-valleys area (Fondo Paviani) and at the center of the Po plain (*Terramara* di S. Rosa di Poviglio).

The **phase 3** is differentiated from the phases 1 and 5 due to the absence - within its excursus - of any distinguished climatic oscillations recognized in literature. At the same time, this phase 3 was characterized by the occurrence of paleo-hydrological phenomena very different both from the previous (of phase 1), and partly also from the later natural one (phase 5: see below). Now, there are large diversion processes of new river branches on a regional scale (see the new Po di Poggio Rusco-Dragoncello-Sermide course), and together the re-occupation processes of previous channels inserted into more ancient river belts (e.g. transition from the Po di Adria 1 to the Po di Adria 1/2). The confluence of the flows of the southern Po branch into the northern one determines an enlargement and increasing of the river bends, following many loops cut-off of the previous narrowest and sinuous meanders.

These fluvial displacements were beginning to the south in correspondence to the main Po river branches (identified starting from the EBA-MBA), to reach, in the RBA, the areas of the lower Modena plain, north of Mirandola, from the Po of the Barchessoni to the Po di Poggio Rusco-Dragoncello-Sermide. When these courses are compared with the mapping of the main anticlinal and syncline arches, that correspond to the Emilia and Ferrara Folds ("Pieghe Emiliane and Ferraresi") buried in the subsoil of the central plain area of the ancient Po river, we can see that these diversions reflect more and more an origin marked by the activation of tectonic thrusts.

This last location of the southern Po branches is supported by some further and significant considerations, such as:

- the branch of the Po di Poggio Rusco-Dragoncello-Sermide, originated from a section of the ancient Po river routes, positioned between two major avulsive nodes (cfr. section extended between Casalmaggiore and Guastalla), in correspondence of an extremely unstable river segment is grafted on one of the main "anti-appenninic" fault recognized in the area (see "Tettonica" in "Istituto geologia di Modena", fig. 9b-9c; BURRATO *et alii* 2012).

- the Po dei Barchessoni meander traces, south of S. Martino Spino (BALISTA 2007), are clearly distorted and compressed: they reveal an abnormal lengthening of their axis, in a northerly direction, a distortion caused by the activity of local "anti-appenninic" fault.

- the sector of ancient river path, where the Po di Poggio Rusco-Dragoncello-Sermide entered in the Po di Adria (section between Sermide and Castelmasa), is located at a short distance and in parallel to the trace of a further anti-Appennine fault, the fault of Carbonara. To this last one the formation of narrow parallel meander loops, which characterize this section of the historical Po river route can be attributed.

- the occurrence of paleo-hydrographic changes documented between the RBA2 and the FBA1, during the phase 3, are more attested along the route of the Po di Adria that ran between Castelmasa and the hydraulic node of Arquà Polesine-Campestrin (Comune di Grignano Polesine) where, at short distance, the two branches of the Saline-Cona and Adria ridges began to bifurcate toward the delta sector.

Conclusively, this situation could be related to paleo-hydrological and paleo-hydrographical parameters changes attributable to factors different from previous one that were more controlled by the climatic oscillations. In fact, for this **phase 3**, we must consider that tectonics, subsidence, and the dismission of installations and earthworks derived from anthropic activities, constituted the major controls on the paleo-hydrographic response of the river channels present in area which in turn were reflected in morpho-fluvial patterns modifications and in the processes of flooding over the previously organized landscapes.

As has been anticipated in the preceding paragraphs<sup>60</sup>, during the unfolding of the **phase 2** (*supra*) and for the entire excursus of **phase 4** (*supra*), the two territories stripes of the SVL and of the HMLP, which extend immediately to the north of the Po di Adria, was connoted by the development of the two main settlements waves, (discreetly displaced spatially and chronologically among themselves): the MBA-RBA the first and the FBA the second. We observe a kind of "positive co-variation" between the frequency and the size of the population density (archaeological sites) for these periods (ATZORI *et alii* 2005; DAL CORSO *et alii* 2012; DALLA LONGA 2015; CAPUZZO *et alii*

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<sup>59</sup> Ponds, peat bogs and marshes filled by peat debris and gyttja.

<sup>60</sup> In part predictable from what was published about the relationships between cycles of population and the precarious "paleoenvironmental situations" in the plain-delta-coastal territories during the Bronze Age in northeastern Italy (see CATTANI, BOCCUCCIA 2018 and CUPITÒ, LEONARDI 2015).

2018) and the geomorphologic stability status linked to the river stages (in incised or in graded equilibrium) that characterized the Po di Adria fluvial regime in this two subsequent **phases 2 e 4**.

The opposite phenomenon is observed for the **phases 1, 3 and 5** (*supra*): it was documented, in fact, a positive correlation between the size and intensity of the hydrographical reactivation processes, recorded by the main river belts at those times, and the rarefaction/disappearance of the settlements, previously co-present on the territory. In fact, as seen during the unfolding of these phases of greater hydrographical and geomorphologic instability, these were the periods during which occurred the major phenomena of flood burial and destruction of the sites. These phenomena, originating from breaching along critical river sections, led to the formation of new crevasse splays and flood channel courses in correspondence of the river banks, and ending in the obliteration of large part of the subsistence site areas, caused by total obliteration of the agrarian and pasture areas.

Turning to the paleoenvironmental evolution of the lower delta and coastal territories facing the sea front, on the base of the arguments developed in previous paragraphs (§ 2, 3 and 4 *supra*), it would be equally indisputable assuming that the phases connected to a greater diffusion/density of the archaeological settlements on the territory, coincided with the stages connoted by a greater degree of "fair-weather controlled coastal construction" of the coastlines (ANTHONY 2013). These phases (**phases 2 and 4**) would mark, among other things, the completion of coastal ridge-sets construction cycles (sets of shorelines and back-shore dunes cordons), which, as know, would have no taken origin during "tempest conditions" (TANNER 1987; TAMURA 2012). Conversely, the more energetic moments of progradation towards sea of more dynamic river branches, (transformed into distributaries in the deltaic plain), would be marked by the formation of "erosion surfaces".

Anyway, albeit within the limits of still scanty documentations acquired, I attempted to identify possible correlations between the various paleo-hydrological parameters that connoted the phases of major paleo-hydrographic inland activity (**phases 1, 3 and 5**<sup>61</sup>) and the parameters associated with recorded positive eustatic oscillations of the coastal areas. These last ones are those proposed within the intervals of High Stationing Period (HST) of marine levels, during the formation of Parasequences 5 and 6 on the Adriatic coast, as documented by marine quaternary geologists (ZECCHIN *et alii* 2014 and AMOROSI *et alii* 2017). More generally, these major phases of geomorphic instability, marked by river progradation have been considered the outcomes of river water flows overloaded by avulsive confluences triggered by climatic oscillations during which prevailing wet and/or humid-cool conditions.

The aforementioned (more energetic) phases (**phases 1 and 5**) would thus appear to have been dominated by the processes marked by deep erosions and together the repositioning of the regional and local avulsive nodes of the lower floodplain rivers and delta distributaries from the most inland *loci*, above all during the conclusion of the Holocene transgressive marine cycles, to the more coastal ones, especially during various episodes connected with the occurring of the Holocene regressive cycles.

These relocations of the avulsive nodes on fluvio-deltaic course paths (BRIDGE 2003) would have been controlled by the phenomena of "back-water effect" (LAMB *et alii* 2012), but most of all, by the characteristics of the river flood regimes linked to the climatic cycles prevailing during each phase.

A possible outcome of the geomorphologic disorders in which the deltaic-coastal sectors were involved, following the extensive erosion of the coastal landforms described above (during the unfolding of **phase 5**), could have been matched to the obliteration of a large part of the previous phases mouth outlets features (above all constructed between advanced RBA phase and first FBA phase). The loss of the reference points on the sea outlets of the river branches used by the traffic networks activated since the Recent Bronze Age may have depended to this fact.

The remarkable erosive paleo-coastal *hiatus* above reported, would then be framed chronologically at a time following the FBA2- FBA3 phases, when the two coastal shorelines of the Po-Adige rivers (still confluent in the MBA-RBA and FBA1) were separated. This is the time of the activation of the detached mouth of the Adige river debouching to the north in the Venice lower lagoon; meanwhile the Po di Adria still fed the Adria branch to the south with its own mouth at sea, during (or until just before) the very first Iron Age (EIA1). This *caesura* seems to have occurred conceivably in co-occurrence/connection with the period of "settlement void" reported between VIII and VII cent. B.C. in large part of the Polesine di Rovigo (PERETTO 2010; CAPUIS, GAMBACURTA 2015). This settlement gap had been previously linked to the extensive processes of flooding caused by the floods of the Tartaro river (BALISTA 2013), unable to converge in the super-elevated Po di Adria ridge, because of the quick overflowing within its natural banks. The Po di Adria 2 paleochannel, during his rapid construction and subsequent abandonment, therefore could have formed a sort of dam that closed the area north to the growing ridge. The formation of a long and imposing ridge-lines, due to super-elevation on the surrounding alluvial plain (under extended processes of overflowing in the riverbed) would fall in the range of cases of the "cycles of regional avulsions " completion, frequently reported in the geological literature (SIMEONI, CORBAU 2009; CORREGGIARI *et alii* 2005a-2005b; STOUTHAMER,

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<sup>61</sup> Which occurred between EBA-MBA, RBA2 and FBA1, and between FBA3 and EIA1.



BERENDSEN 2007). The processes connected to these cycles are characteristic of the main waterways that flow through the fluvio-deltaic plains with a low depositional gradient, such as the courses of the Po branches that crossed the Veneto-Emilia plain during the Bronze age. These lowland rivers, after completing the formations of the single deltaic lobes, firstly fed by distinct river branches, converge thereafter in a new great monocursal course, that wanders into a new alluvial belt, as is the case of the formation of the Po di Ferrara (Po di Spina) at the beginning of the Iron Age.

## GLOSSARIO

Early and Middle Bronze Age (EBA, MBA) = Antica e Media Età del Bronzo;  
Recent and Final Bronze Age (RBA, FBA) = Età del Bronzo Recente e Finale;  
Early Iron Age (EIA1) = Prima età del Ferro 1;

1 Ky (kiloyear) = 1 millennio;  
Adige river = fiume Adige;  
aggradation = accrescimento verticale;  
alluvial fan = ventaglio alluvionale;  
back-shore ridges/dunes = dune eoliche di retro spiaggia.  
longshore/littoral ridge = cordone litorale;  
crevasse splay = spagliamento di rotta;  
distributary delta channels = canale distributivo deltizio;  
flood-channel = canale di rotta;  
fluvial breach/route = rotta fluviale ;  
High-Middle-Lower Polesine (H/M/LP) = Alto-Medio-Basso Polesine;  
paleochannel = paleoalveo;  
Po di Adria river = Po di Adria;  
Po river mouth/outlet = bocca di foce del Po;  
progradation = accrescimento orizzontale;  
ridge-set bundles = fascio di creste litorali;  
river channel belt = cintura di canale fluviale;  
river discharges = portate fluviali;  
Southern Verona Lowlands (SVL) = Valli Grandi Veronesi Meridionali;

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