*Geogr. Fis. Dinam. Quat.*
*32 (2009), 135-144, 4 figg., 1 tab.*

STEFANO CREMONINI (*) & ELEONORA SAMONATI (*)

# VALUE OF ANCIENT CARTOGRAPHY FOR GEOENVIRONMENTAL PURPOSES. A CASE STUDY FROM THE PO RIVER DELTA COAST (ITALY)

ABSTRACT: CREMONINI S. & SAMONATI E., *Value of ancient cartography for geoenvironmental purposes. A case study from the Po River delta coast (Italy)*. (IT ISSN 0391-9838, 2009).

A set of four large-scale pregeodetic maps was studied. They depict the Po River delta ancestor in the late-16th century AD (before the year 1604), an extremely important area for the geoenvironmental and historical evolution of Northern Italy at the beginning of the Little Ice Age. The maps are very detailed and complex. This characteristic involves some problems relating to accuracy and comparison with present-day cartography. This first attempt at map georeferencing is required in order to make possible original coastline location in areas that do not exist today because of sea erosion. Nevertheless, a further attempt is already being made for achieve a better understanding of the maps. Inner details and manifest errors were highlighted so as to better appraise the reliability of the maps and the authors' survey methodologies. Furthermore, a particular and highly peculiar geomorphological object (i.e. an offshore megabank) was analyzed and rejected as a completely untrue ancient landscape tract. Hence, the really interdisciplinary character of this kind of studies must be ever taken into consideration and critical map analysis should not merely be seen as a useless and time-consuming analytical tool since the fortuitous preservation of ancient documents can dispel wayward interpretations in geoenvironmental reconstruction.

KEY WORDS: Po River delta (Italy), Pregeodetic cartography, Map georeferencing, Landscape analysis, Offshore bank.

RIASSUNTO: CREMONINI S. & SAMONATI E., *Valore della cartografia storica a fini geoambientali. Un esempio dalla costa dell'area deltizia del Po (Italia)*. (IT ISSN 0391-9838, 2009).

Si presenta lo studio di un gruppo di quattro carte pregeodetiche a grande scala che descrivono l'apparato deltizio padano, progenitore dell'attuale, alla fine del XVI secolo (anteriormente al 1604), area di estrema importanza per l'evoluzione geoambientale e storica dell'Italia settentrionale agli inizi della Piccola Età Glaciale. Le carte sono estremamente dettagliate e complesse. Ciò comporta problemi relativi all'accuratezza e comparabilità degli esemplari con la cartografia attuale. Questo primo approccio alla georeferenziazione diretta degli esemplari cartografici si è dimostrato indispensabile per tentare di procedere alla restituzione dell'originale posizione della linea di costa oggi non più esistente a causa dell'erosione marina. Un ulteriore approccio, indipendente dal presente, è già in corso per tentare di raggiungere un migliore livello qualitativo nell'analisi veterotopografica. Dettagli topografici interni ai documenti e patenti errori compiuti dagli estensori vengono illustrati al fine di meglio comprendere l'affidabilità degli esemplari e le metodologie di rilevamento adottate dai cartografi.

Inoltre si analizza un peculiare soggetto «geomorfologico» (un megabanco sedimentario al largo) proposto da una delle carte analizzate, dimostrandone l'inverosimiglianza come tratto del paesaggio fisico coevo. Quindi il carattere realmente interdisciplinare di tale tipo di studi deve sempre essere tenuto in considerazione e l'analisi critica (anche filologica) dell'esemplare antico non dovrebbe essere percepita soltanto come un superfluo e dispendioso strumento analitico proprio perché la fortuita casualità della conservazione dei prodotti cartografici può anche risultare sviante nelle ricostruzioni paleogeoambientali.

TERMINI CHIAVE: Delta del Po, Cartografia pregeodetica, Georeferenziazione cartografica, Analisi del paesaggio, Banco sedimentario al largo.

## RESEARCH AIM AND INTRODUCTION

It is usual to use and deal with ancient kinds of documents, cartography in particular, for geoenvironmental research purposes. However, the ancient documents are often used without any sort of prior critical, i.e. philological, analysis as this step is seen as a pointless waste of time. Within such a research perspective, the coastline evolution and the magnetic declination angle play a preeminent role. Therefore, the usual questions in this field are: i) What is the «topographical truth»? ii) What were the measurement errors? iii) Which elements and data can be used to «restore» old, coeval environment tracts? iv) Is it possible

(*) *Dipartimento di Scienze della Terra e Geologico-Ambientali, Università degli Studi di Bologna - Via Zamboni 67, 40126 Bologna, Italia.* (stefano.cremonini@unibo.it)

*Our thanks go to G. Bitelli (Dipartimento DISTART, Università di Bologna), L. Masotti (Dipartimento di Economia, Sezione di Geografia, Università di Bologna), C. Tonini (Museo Correr, Venezia), M.L. Scarin (Dipartimento Scienze della Terra e Geologico-Ambientali, Università di Bologna).*

*Study funded by MURST-RFO ex-60% (M.L. Scarin, 2006-2007).*

to measure the old magnetic declination reliably? The last question will not be dealt with here because of its intrinsic complexity.

A set of four maps concerning the geographical area of today's Po River delta ancestor had already been partially analyzed by Cremonini (2007b, therein references). Its interest consists in the fact that the maps (actual *ante litteram* technical maps) portrayed, at the end of the 16$^{th}$ century AD, a lowland coastal area that is very important as concerns the hydrographic, environmental, historical and economic evolution of Northern Italy.

The maps are very detailed and complex. Furthermore, they were conceived in a pregeodetic cultural environment. This involves problems concerning the precision, reliability and comparability of the maps with present-day cartography. Here a first georeferencing approach is put forward but another series of attempts is already seeking to achieve a better understanding of the maps.

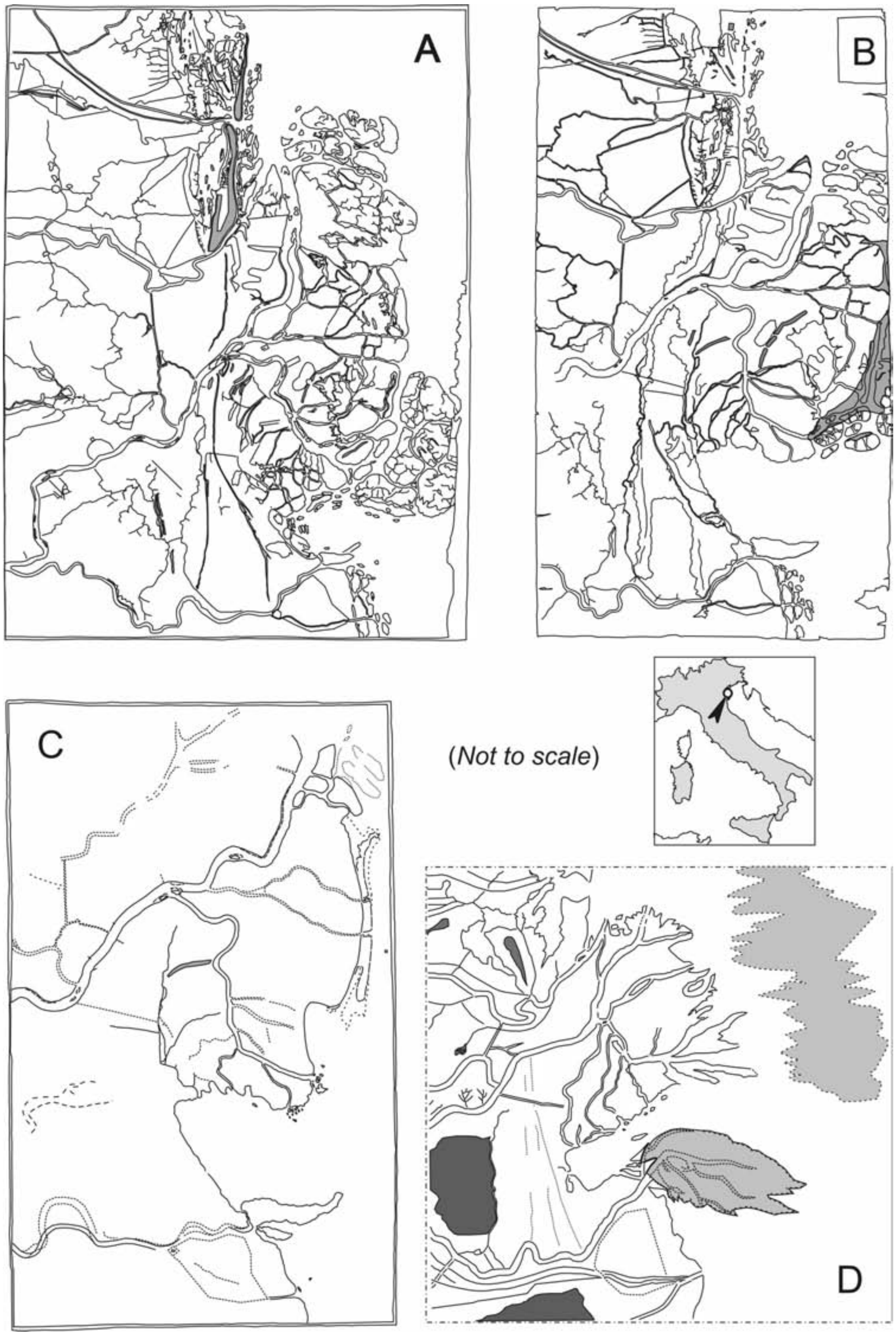
The particular importance of this map set is due to the fact that they were made in a single decade (1592-1603) yet, in spite of this, they depict the same coastal area before 1604 quite differently. That was the year when an old Po river delta lobe system died and a newer one (i.e. present-day Venice Po River delta system) began to grow (Ciabatti, 1966; Correggiari & *alii*, 2005a; Correggiari & *alii*, 2005b; Cremonini, 2007a). The specific interest in the sedimentary environment lies in the fact that the newest of these maps records an unusually large offshore sediment bank, closely resembling an offshore shoal degradation system like the one proposed for the Mississippi delta complex by Penland & Boyd (Coleman, 1988), whereas the other three maps do not show the same kind of physiographic tract. Therefore, the significance of this remarkable difference warrants analysis.

## MATERIALS AND PREVIOUS ANALYSES

The original set of maps is reported in (Cremonini, 2007b), pursuant to the provisions of Italian law, and cannot be reproduced here again. Therefore, only an essential, faithful line-draw of each map is shown (fig. 1): from here on the four maps will be named A, B, C, D as in the figure. The original samples of the first three maps are preserved at the Italian State Archive in Venice, where they had been unknown of at least until 1881 (Marinelli, 1881). In particular, the fourth one is archived at the ancient Archiginnasio Common Library in Bologna and had already become famous in the 17th century (Cremonini, 2007b). During the 15th-17th centuries, Venice was an important cultural centre where the most famous treatises dealing with geography and related surveying techniques were printed. Ottavio Fabri, the author or co-author of the first three studied maps, a leading figure in the Venetian technical environment (Salgaro, 2006), almost certainly knew of the works of Mercator's teacher, Gemma Frisius, and invented a peculiar instrument (Fabri, 1598) which he used to survey the lands drawn in his maps. Also, the author of the fourth map, G.B. Aleotti (1546-1646), was a very famous architect and hydraulic engineer (Petrella & *alii*, 2006) and a personal friend of Fabri, so that an exchange of information between them is certain.

The first two samples (fig. 1 A, B) are definitely date back to the year 1592, as stated in the document itself. The meaning of the construction of a double map of the same area in the same year is still unclear but should probably be seen as a common ancient practice as the land survey techniques had not yet been completed (Tumiatti, 2005). This detail probably conceals the Venetian Government's need to possess a truly reliable cartographic representation of the Serenissima territories devoted to the fiscal levies (Marinelli, 1924; Casti Moreschi, 1993), in particular those pertaining to the recently emerging coastal areas of the deltaic zone involved in land reclamation strategies. It is possible that some inner details of the second map (fig. 1B) had been corrected in 1599, when a new official topographic survey set was required by the Government immediately before the beginning of the complex works that, in the following four years, led to the creation of a new artificial channel for the Po river embankment. On that occasion, the third map (fig. 1C) was also produced (Tamba, 1970), or at least profoundly corrected, as suggested by some detail shadows lying along the northern coastal areas (i.e. the northern islets, etc.). Being pregeodetic cartography (i.e. not conformal, equivalent and equidistant) the original scale is not constant throughout every map and the average original scales along the main drawing axis (N/S-W/E) are about 1:10,217-10,104 (A), 1:12,250-10,988 (B), 1:11,160-10,935 (C), respectively, not corresponding to the drawn graphic scale (approximately: A = 1:10,616; B = missing; C = 1:11,074): for this reason the original scale bars (using three different local, non metric unit systems) are not reported in the figure. Hence, they are truly technical maps, mainly showing river courses, channels and only few villages or cities of a 35x20 km wide territory, over a compound sheet-bases measuring 3.47x 2.5 m (A), 2.85x1.59 m (B) and 2.34x1.42 m (C), respectively. The fourth map (fig. 1D), published in 1603, is the most recent of the set, but it had probably already been prepared in 1598-99. The history of this map is both complex and troubled (Cremonini, 2007b). The original scale of the latter map is about 1:269,000 and it represents a very huge territory on a 0.60x0.45m sized sheet. Only a small portion (4.9%) of the original map was used in this study. Furthermore, this map precedes another two more detailed samples, made in 1613 and 1614, respectively (Cremonini, 2007b), describing the same areas and the subsequent evolution of the new Po riverbed. None of these drawings show any sort of geographical graduation, and so they must be seen as simple and rough plane projections-like, surveyed in the topographic field (50 km in diameter) using Renaissance techniques and instruments (Vagnetti, 1970; Docci & Maestri, 1984). In particular, Map 1A preserves two kinds of differently-sized survey grids as palimpsest (Cremonini, 2007b) of unclear dating, not discussed herein, perhaps also proving the use of the compass as a normal tool during the field surveys. This represented a major source of error in the point locations.

FIG. 1 - Line-draw of the four original 16th century maps: A) Fabri O., 1592; B) Pontara G., Fabri O. & *alii*, 1592; C) Lorini B., Fabri O. & *alii*, 1599; D) Aleotti G.B., 1603 (Cremonini, 2007b: therein references). The original bar scales are not shown since unrealistic and non-metric. The grey tones indicate: A) sand dunes fields; B) submerged areas; D) offshore megabanks (light tone), alluvial basins (dark tone). In C) the north-eastern dotted islets were erased.




Errors in azimuth and bearing readings and in the associated length measurements contribute to generating maps showing angles quite different from the actual ones (see below).

The orientation of maps A and C was performed by making the long sides of the table parallel to the coeval magnetic North ($N_m$) direction, coinciding with the Tramontana bar of the wind-rose; but they display different declination angles in respect to the real geographic North, probably $N_m$ of Map A being incorrect. Map B does not record the $N_m$ direction but could be assumed as being parallel to the map long-side, thus perfectly resembling the $N_m$ indicated on Map C.

Despite the connate errors, the original drawing quality of the maps is high and their state of preservation is generally good. Only Map B appears to lack a limited part of the deltaic coastline details, probably due to a resection of the worn map edge (e.g. see the stuck-on cartouche). All these factors and considerations can help to explain the high quality level of the maps studied here and their interest and value as cultural heritage assets.

A line-draw of Italian Military Geographic Institute (IGM.I) today map (1950, scale 1:100.000) is also shown (fig. 2A-B) to ease the comparison of the deformations characterising the set of the historical maps. A simple comparison of angle 16 between maps 1A and 1B (fig. 2C-D), very well highlights an inner, severe general rotation effect of the Po delta lobe of A *vs*. B. The set of drawn angles (fig. 2B) may suggest the clear cartographic non-conformity of the maps. All the previous remarks suggest that a geoferencing processing is required to better compare and understand the maps.

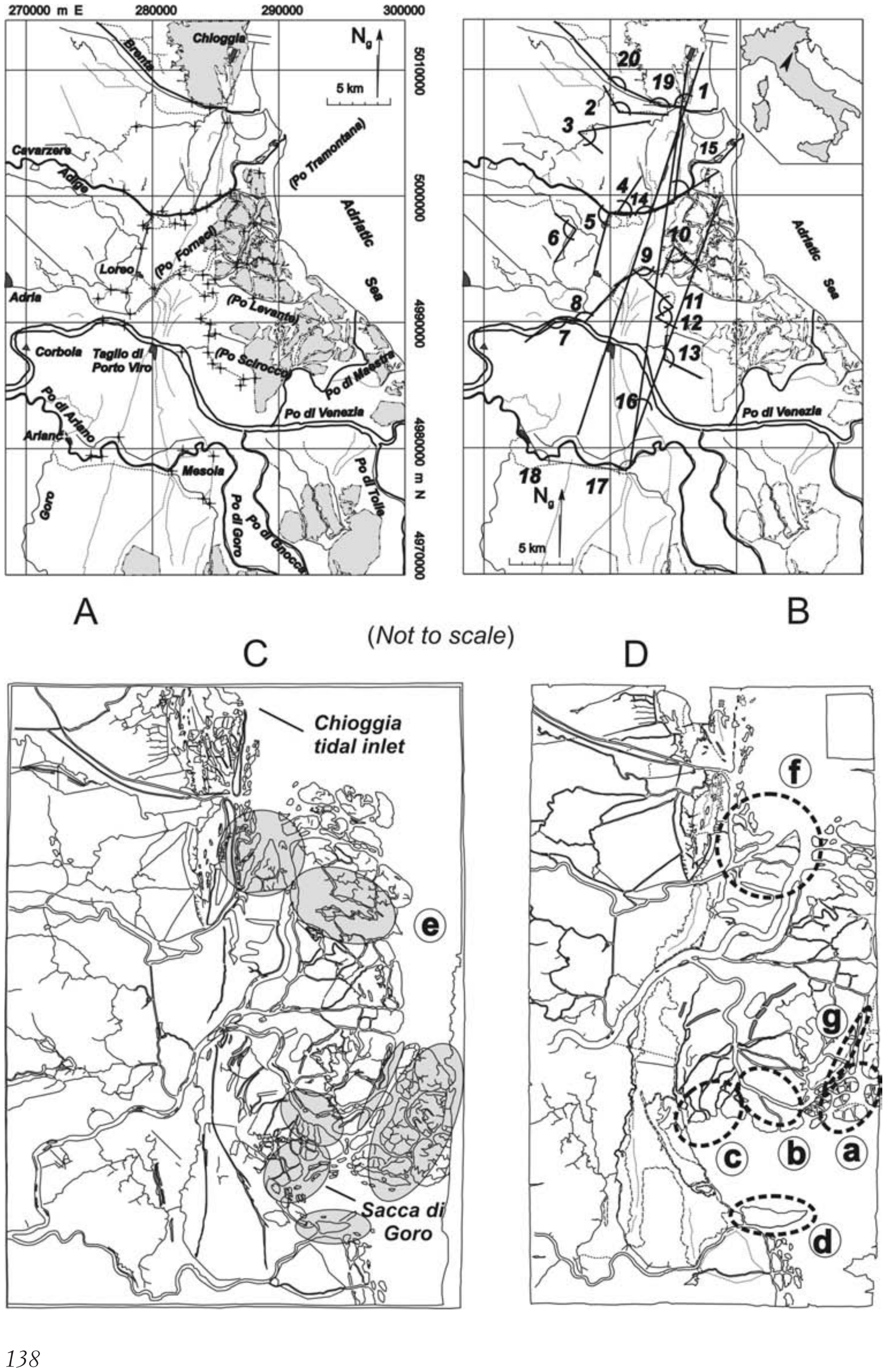



FIG. 2 - A) Essential line-draw of today's physical landscape (redrawn from IGM. I 1:100.000, sheets 65 and 77) with the LMKs location, salt marshes or lagoon (grey tone) and paleoriverbed names in brackets. B) Some selected deformation angles to be referred to subsequent (C and (D details. C) Map A (Fabri) essential line-draw: wrong areas in grey tone. D) Map B (Pontara) essential line-draw: the same wrong areas as in (C are shown to be compared.

## METHODOLOGIES

The previous qualitative observations make necessary a first attempt at a more quantitative approach. So the photographic images of the original maps (Cremonini, 2007b) have been accurately digitized by means of an ordinary drawing software, subdividing the geographical objects into 15-20 information layers. A set of 64 points (fig. 2 B) was linked to the resulting line-draws as landmarks: 62 of these points were used for maps A and B, 28 for Map C and 45 for Map D. Landmarks (LMKs) must be regarded as selected points less reliable than the usual topographic benchmarks (Tang & Crovella, 2004). They are points clearly recognizable both in the ancient map and in today's equivalent or in the aerophotographic palimpsest. The analysis of palimpsest was only performed in selected areas, where the present-day landscape does not preserve clear evidence of the old geomorphological units. This kind of auxiliary analysis was performed on an original, unpublished flight made in 1964 (personal communication by Prof. M. Ciabatti) and it has been integrated by means of Google image analysis. Unfortunately, only 50% of the ancient Po delta-ancestor area is now reclaimed, whereas the remaining part is still or freshly submerged as a result of land subsidence. Due to these limitations and to the fact that four hundred years ago these areas were barely inhabited, being newly generated lands, the LMKs were chosen coinciding with: i) villages (or cities); ii) single, isolated buildings still existing; iii) channels and/or river junctions or bifurcations; iv) maximum curvature points of the external band of a river curve or meander loop; v) single peculiar points along the coastline. This implies that the LMK location pattern is not homogeneously distributed throughout the whole of studied area, depending primarily on the geometry of the hydraulic network. The preliminary location of the LMKs was performed on fourteen 1:25.000 topographic maps related to IGM.I 65 and 77 1:100.000 Sheets (6$^{th}$ Edition). The location error ranges between 0 and 200 m approximately, with a mean value of 125 m, whereas maximum values are recorded at points located in the north-eastern reach of the delta lobe. At each point N,E coordinates were attributed according to UTM-ED50-33T(N) km-grid by means of direct reading on the IGM.I original maps with a 10 m precision.

A second order polynomial transformation (ArcMap of ARC-VIEW 9.2 suite) was adopted as a georeferencing tool for spatial adjustment of the points set: the transformation was only applied once and not reiterated. This kind of transformation is thought to be widely adequate (albeit not completely satisfactory) for this first-step approach because reliable reintegration techniques for disappeared ancient land areas, eroded by the sea, do not exist. The georeferencing visual output used a simplified base 1:100.000 IGM.I line-draw (fig. 2A).

Special attention has had to be paid to Map D because of its highly peculiar inner characteristics. After a first fruitless georeferencing attempt of the whole sample, the map was split into two parts (i.e. northern, southern) approximately along a line (fig. 3) resembling a real physical connection line still existing in two other subsequent maps drawn by the same author, dating back to the years 1613-1614 (Cremonini, 2007b). Each part was then independently georeferenced as indicated above and successively reassembled as well as possible (fig. 4D).

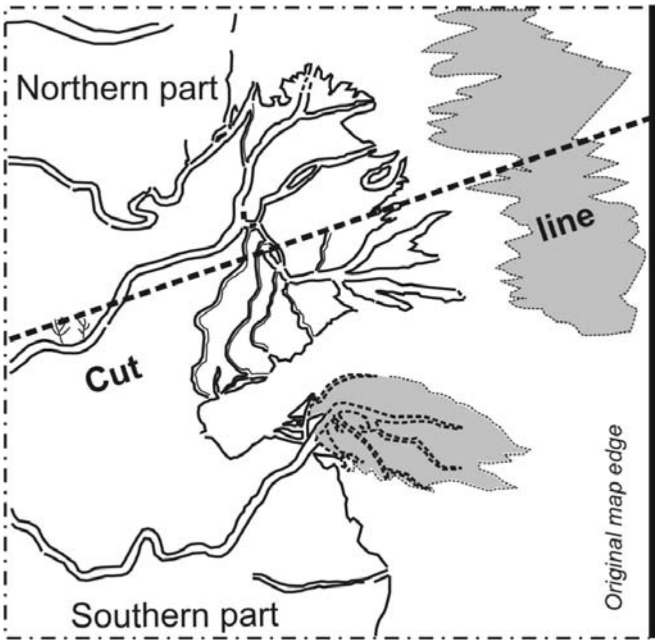


FIG. 3 - Cut line (straight dashed line) adopted for the Map D georeferencing.

## RESULTS

Figure 4 shows the four maps after the georeferencing process. They are equally scaled (e.g.: the 10 km UTM grid) and the modern coastline is shown as an inner reference term. The ranges of single-point residual error (in metres) for each map are listed in table 1. The residual errors are the sum of the georeferencing processes and of the implicit ancient cartographic (i.e. field survey and final restitution) errors. They appear to be very high but are not unusual in ancient cartography georeferencing performances, ranging from 100 m up to about 10 km (Bayram & *alii*, 2004); Timar & *alii*, 2008). Hence, for this first-step

TABLE 1 - Residual errors of the georeferencing processing

| Map | A | B | C | D northern | D southern |
|---|---|---|---|---|---|
| Residual error range (m) | 104-1962 | 82-1532.7 | 118-1282 | 351-1730 | 179-1448 |
| RMS error (m) | 706.6 | 534.8 | 530 | 1270 | 695 |

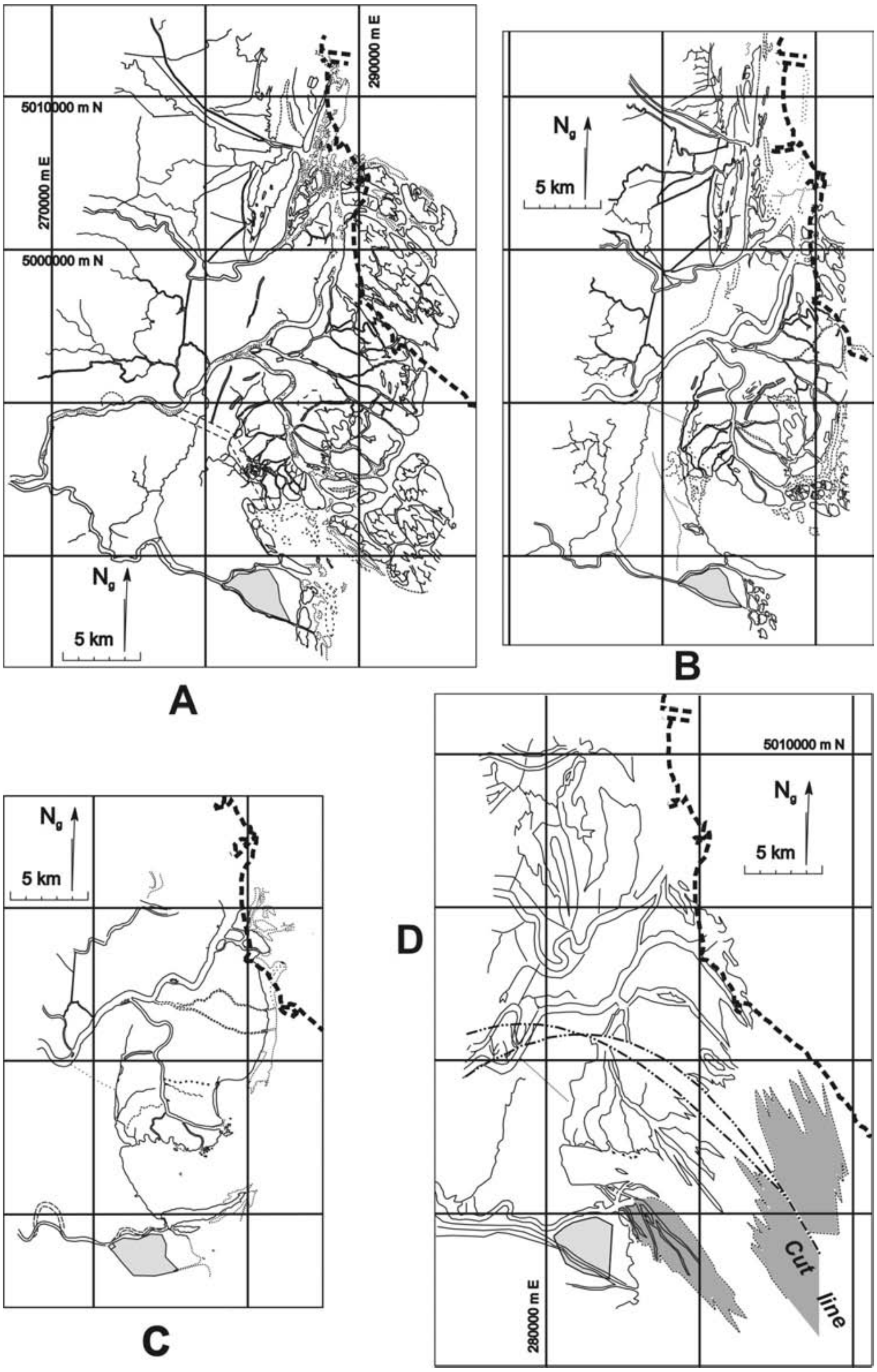



FIG. 4 - Georeferenced maps with 10 km UTM grid: A) Fabri O., 1592; B) Pontara G., Fabri O., 1592; C) Lorini B., Fabri O. & *alii*, 1599; D) Aleotti G.B., 1603. The grey tone shows the Mesola defence-walled area. The bold, dashed line indicates modern coastline.

approach the results appear to be satisfactory even if local limited disagreements in the physiographic features persist, especially in peripheral areas of the maps. Although an absolute (metric) comparison may be still inconvenient, discrepancies among the four maps are qualitatively quite evident.

Processed Map B shows the best qualitative fit with a high number of detail overlaps in respect to present map. The most problematic areas are in the core and eastern delta reaches, in particular, between the Levante and terminal Scirocco Po branches. The geometry of these rivers is fully valid but they are shifted by about 1 km northward and southward, respectively. Also Mesola defence-wall and the last reach of Po di Ariano are slightly shifted southward. The Tramontana northern Po mouth with related islets, Adige and Brenta rivers almost perfectly match the preserved geomorphology. The good fit of the eastern delta coast position is more difficult to evaluate but a cross-comparison with Map C could suggest a possible very low error. Map C is very essential and Levante branch is shifted northward by about 400 m, whereas the coastline at the mouth of this branch could result about 350 m further westward than the «real» one and the waterfront of the southern side of Sacca di Goro gulf is shifted 600 m inland. Map A shows a very high (about 1,800 m) apparent eastward shift of the coastline of Levante branch in respect to corresponding Map B reach and a severe southward rotation effect of the Levante branch, whereas other anomalies (fig. 2 C-D) are quite evident (see below). Map D shows a good reliability only in peripheral area south of the Ariano branch, directly well known to the author. In all other areas, the deformations are too high because of the already high original deformations of the map itself.

From a paleohydrographic point of view, Map B indicates the birth of new crevasse channels starting from Scirocco branch near Mea middle point; in Map C the recent Porto Caleri channel probably appears (missing in A and B), and Map D already shows Gottolo (= little channel) of Valle Morosina: this new setting is also stated by a 1599-1604 Bertelli map (Ceccarelli, 1998: fig. 41).

## DISCUSSION

The aim of this analysis is to attempt to state the reliability of coastline geometry for further comparison and inference. Here the term «coastline» defines the direct boundary between the sea and the hinterland, excluding a series of islets and secondary channels lying immediately offshore as they were highly dynamic and transient geomorphological tracts: so when reference is made to the latter tracts, the terms «islet-envelope» and «islet cluster» will be used.

The studied maps show striking differences that can be recognized and categorized into four groups: i) survey errors; ii) consciously induced corrections (in author's own interest); iii) interpretative exaggerations; and iv) true physical change in the geomorphological details. The recognition of the first three groups allows for a better understanding of the fourth.

A simplified interpretation of the relative chronology of the first three maps must start with the declared relationships between B (1592) and C (1599). Map D was edited in 1603 but had already been drawn in 1598-99, even if probably only partially surveyed (local controls) on the field: so it is probably a late product. Map A (1592) might be seen as the first prototype or forebear of B because: i) the author is unique and will be always present as co-author in the subsequent maps, so he was the art master; ii) the drawing of details appears more approximate as compared with Map B; iii) severe deformations and survey errors are recorded that do not exist in B (a bad product cannot be sold if a better one already exists); iv) it is the only map recording inner details of its constructive techniques (i.e. magnetic and other grids in palimpsests). The mismatched historical significance of the existence of two maps of the same area produced in same year (1592) by the same author or co-author cannot be solved here. But it is a very important matter because Maps A and B lead to quite a different size and location of the coastline details, especially in the northern and southern deltaic areas.

A preliminary comparison between maps A and B (fig. 2C-D) highlights some apparently large differences in the ancient description of the same morphological objects; in particular, in A there is: i) a general enlargement (about twice) of the «archipelaghos» of the offshore islands (islets-clusters) (a); ii) errors (shortening) in the restitution of the terminal reach of Po di Scirocco (b); iii) severe location discrepancies of the inner coastline of Sacca di Goro gulf (c); iv) different length of the «Mesola finger» (d); v) a wide area in the northernmost reach of the delta lobe (e) clearly unrealistic and probably voluntarily added by the cartographer; vi) a severe reduction in the angle existing between Adige and Tramontana branches (f), possibly correlated to the previous error; vii) enlargement of former backcoastal channel (g). Another cross-comparison between Map A, and Cristoforo Sorte's (1594) map «Carta del Padovano e del Trevigiano» (Romanelli, 2004) suggests that A probably is really grossly wrong in some details. In fact, in Map A, the northern delta coast is inexplicably northwards shifted by at least 2 km or even more, so that the sediments of the Tramontana branch mouth really appear to have already reached the mouth of the Brenta River and not just the mouth of Adige River (Tumiatti, 2005). In such a way they would seem to approach the first southern (Chioggia) tidal inlet of the Venice lagoon. Strangely, however, no other map displays this crucial detail. A similar sort of exaggeration affects the relative location of the pocket-beach coastline in the southern Sacca di Goro: in this case, the error is well masked by means of a considerable lengthening of minor inland channels. If Map B is taken as the frame of reference, then the topographic details of Map A fully show the described discrepancies, errors and inaccuracies. Furthermore, Map A highlights a number of the errors so high as to make their explanation in the simple terms of the topographic survey techniques rather difficult. Astonishingly, seven years later, Map C paid particular attention exactly to the problematic areas of Map A as indicated by the backsight lines drawn therein.

Here Map B is assumed to be the best cartographic product of the set of four maps analyzed, at least from a merely qualitatively standpoint (as the residual error problems cannot be studied here). The object widths (e.g. riverbeds) appear to be more reliable; the detail is accurate; the local geometries are similar to the real ones.

Map C shows some inner and coastal (Sacca di Goro) topographic details perfectly equal to homologous Map B ones, in such a way as to also state the apparently high quality of Map B. But it also shows a severe change in the whole of the eastern and northern coastline profile, and it is so peculiar that it cannot be a mistaken result. This map also suggests that at the technical meeting on July 12th, 1599 held in the village of Loreo (Ceccarelli, 1998), only an old previously surveyed map was produced, and then simply corrected in some details. In fact, some prior morphological features (at least the islet cluster of the northern delta mouth) were erased by a new cover layer of water-colour.

Map D is highly deformed and at places often unclear and misunderstood by the author himself. In particular, Aleotti never understood the true net relationships existing among the main inner delta branches (Levante and Scirocco), even in the subsequent newer map editions; Adige and Brenta river courses are approximate and do not really appear to have been updated.

Now it is possible to attempt a last preliminary interpretation in a paleoenvironmental key. Map A still shows emerging coastal details and a southern severely seaward islet-envelope protruding as a possible legacy of a recent, former higher energy stage of the Scirocco branch (as stated by a written text along the river channel). It is unclear whether this part of the map had been surveyed a few years before 1592 but is nonetheless possible. The wide size of the islet clusters (if realistic and not exaggerated) leads us to think of a possible old delta lobe experiencing a subsidence warping with a related submersion trend inducing a sandy-muddy tide/lagoonal plain (e.g. small inner channels). The Northern islet cluster represents the main active delta lobe in 1592 (e.g. islets without inner channels). Map B shows the same clusters but in the southern one the islets are smaller and the inner channels wider than in Map A. This striking difference is reinforced by a later series of corrections affecting the areas between the coastline and islet clusters showing an enlargement (due to a possible local subsidence) of a pre-existing backcoastal channel still preserving the originally subaerial morphologies. In Map C the southern islet clusters had already completely disappeared, while the northern one had deeply changed; the coast is severely smoothed and a long sandy spit barrier appeared resembling a big bone. Furthermore, the «Mesola finger» (left, Ariano branch asymmetric delta wing) appears to be consistently accreted in length. Map D can be hardly compared with the previous ones and the large, continuous offshore megabank, partly resembling the southern islet cluster, could simply be a late remembrance of old and out-of-date information accruing from previous authors or unreliable personal field investigations (Cremonini, 2007b). In fact, the first drawing proof, dating to 1598-99, was coeval to Map C, already showing a quite different coastal morphology. No traces of offshore megabanks are recorded in other older maps such as the Alvise Donato (1531-32) *Carta della Laguna* (Bevilacqua, 1974) and Nicolò dal Cortivo (1534) map (Zunica M, 1974). Furthermore, Po di Tramontana branch was not yet born and Adige river terminal reach is straight and with no sort of own delta lobe. Finally, the megabank does not exist, not even in the revised 1613-1614 Aleotti delta maps.

The similarity of Map D megabank size and distance from the coast with the Po di Pila flood events suspension plume (Gabbianelli & *alii*, 2000) is astonishing. Furthermore, Aleotti's outer boundary bank perfectly fits the offshore diffusion limit (about 10 km) for the centennial flood plume (Milligan & *alii*, 2007). Unfortunately, no comparisons have been found for any such offshore bank anywhere in the world (Cremonini, in progress), except for the case of a large fine-grained shoal in the middle of the paleogulf of Ayutthaya in Thailand (Tanabe & *alii*, 2003). However, in that case the bank is a inherited long-term structure that originated during the early Holocene lowstand conditions and not a simple prodelta-related structure. Nor did the northernmost Venice offshore «Banco di Cortellazzo» (Cremonini, 2007b) exist as an active submerged low water morphological unit, because its top elevations are equal to today's bottom depths (Baso & *alii*, 2003: no. 119). Therefore, no comparisons seem to exist for Aleotti's megabank at all, which was probably only a speculative drawn tract, even if in the 16$^{th}$ and subsequent centuries the submerged beach model was really quite different (very low-water) from the present one and much more seaward expanded (Cremonini, in progress), as has to be expected within the general framework of a more positive littoral regime balance than today's. The model of quite a wide submerged beach appears to be a sort of time-persistent cartographic topic even in the case of the northernmost barrier islands of the Venice lagoon, where in 1692 the Vestri map (Bevilacqua, 1970: fig. 11) and many others show a pronounced submarine sand spit at each of the four lagoon inlets, coupled with their long and southward curved tidal channels induced by the offshore North Adriatic drift current.

On the contrary, it is possible that Aleotti recorded real sedimentological evidence in his map (D) when he indicated the southernmost bank located offshore from the Po di Ariano branch mouth (fig. 1 D). The drawing suggests the existence of a fine-grained low bottom area, protected from the Bora wind's reworking activity by the larger delta complex of Po delle Fornaci (= Scirocco + Levante + Tramontana). This peculiar characteristic is also supported by a map of Crescenzio (1599-1604) showing widespread low-water bottoms and almost emerging underwater dune fields opposite the Levante, Scirocco and Ariano branch mouths (Ceccarelli, 1998: fig. 42).

This southwards deflected minor bank is asymmetrical and at its top displays an unusual series of very long distributary subaqueous protochannels. The emerging «Mesola finger» is related to this peculiar set of forms. Danti's Map (1587-1590) «Ferrariae Ducatus» (Malafarina, 2005) well illustrates the origin of this unusual asymmetric coastal morphology, indicating the severe axial progradation of the *Ariano* delta mouth to be the result of the interplay between delta sedimentation mechanisms and a dominant southwards directed longshore current (exactly the opposite to what had been happening immediately southwards). The very same morphology would be repeated about two centuries later by Punta della Maistra (Stella, 1911) in a more southern reach.

This set of peculiar observations probably led the author to propose a northwards extension of this *ante litteram* model (Cremonini, 2007b) to explain the low-bottom areas opposite the Scirocco and Tramontana branch mouths that would have persisted for a little time longer.

## CONCLUSIONS

The results of the study portray the many problems relating to the local coastal evolution, more interesting than had been believed up to now. The existence of four different maps representing the same geographical area in the same short (decadal) time span is a fortuitous and very rare historical case, as well as being a unique opportunity.

The maps reproduce the same objects with an astonishingly high degree of accuracy even if there is no robust geographical frame capable of providing a definite points location. The most problematic factor is the impossibility of a reliable restitution of the original eroded coastline. Hence the need to apply a more appropriate and more accurate georeferencing method becomes quite evident. In spite of this drawback, the multiple comparison allows us to state that the Aleotti map (fig. 1D) cannot be assumed to be a reliable data source for inferences concerning the 16$^{th}$ century coastal and marine dynamics nor the fluvial sediment transport rates notwithstanding its undoubted scenographic value. Only mere chance was responsible for the broad diffusion and knowledge of this historical map across the European cultural environment of the 17$^{th}$-18$^{th}$ centuries.

If the megabank was not a real natural object, then it is possible that it could have originated from a bad copy job from the maps of other authors (Fabri?) or even from an attempt by Aleotti to suggest a personal interpretative model for the local coastal erosion occurring in the last decade of the 16$^{th}$ century, resulting from a merging of various sources of information, modified by an author's experience acquired in the southern delta reaches. In any case, that information source appears to be rather dated.

Hence, at times the casual nesting of a set of compelling evidence and suggestions offered up by the ancient primary data sources can be a very dangerous analytical tool unless it is supported by an adequate critique. Nevertheless, the question as to what the real truth of the information content offered by an ancient map corresponds remains unanswered: that is, if it is the one proposed by the original document or, conversely, the one suggested by the georeferenced derived-sample.

## REFERENCES


BASO G., SCARSO M. & TONINI C. (2003) - *La laguna di Venezia nella cartografia storica a stampa del Museo Correr*. Marsilio, Vicenza, 137 pp.

BAYRAM B., BAYRAKTAR H., HELVACI C. & ACAR U. (2004) - *Coast line change detection using CORONA, SPOT and IRS 1D images*. International Archives of Photogrammetry and Remote Sensing, 11, 1-5.

BEVILACQUA E. (1970) - *La cartografia storica della Laguna di Venezia*. In: (without Eds.), «Mostra storica della Laguna veneta», Stamperia di Venezia, Venezia, 141-146.

BEVILACQUA E. (1974) - *Una mappa della laguna di Venezia e del retroterra lagunare di Alvise Donato (1531-1532)*. Memorie della Società Geografica Italiana, 31, 109-115.

CASTI MORESCHI E. (1993) - *Cartografia e politica territoriale nella Repubblica di Venezia (secoli XIV-XVIII)*. In: Institut Cartografic Catalunya & Universidad Autonoma Barcelona (Eds.), «La cartografia italiana», Institut Cartografic de Catalunya, Barcelona, 81-101.

CECCARELLI F. (1998) - *La città di Alcina. Architettura e politica alle foci del Po nel tardo Cinquecento*. Il Mulino, Bologna, 226 pp.

CIABATTI M. (1966) - *Ricerche sull'evoluzione dell'antico Delta Padano*. Giornale di Geologia, 34 (2), 381-406.

COLEMAN J.M. (1988) - *Dynamic changes and processes in the Mississippi River delta*. Geological Society of America Bullettin, 100 (7), 999-1015.

CORREGGIARI A., CATTANEO A. & TRINCARDI F. (2005a) - *The modern Po delta system: lobe switching and asymmetric prodelta growth*. Marine Geology, 222-223, 49-74.

CORREGGIARI A., CATTANEO A. & TRINCARDI F. (2005b) - *Depositional patterns in the Late Holocene Po delta system*. In: Giosan L. & Bhattacharya J.P. (Eds.), «River deltas. Concepts, models and examples», SEPM Special Publication, 83, 365-392.

CREMONINI S. (2007a) - *Some remarks on the evolution of the Po River plain (Italy) over the last four millennia*. In: Marabini F., Galvani A. & Ciabatti M. (Eds.), «China-Italy bilateral Symposium on the coastal zone evolution and safeguard», Proceedings of CNR Meeting., Bologna, November 2007, 17-24.

CREMONINI S. (2007b) - *Questioni di geomorfologia costiera del delta del Po anteriormente al 1604. Evidenze dalla cartografia storica*. Annali di Ricerche e Studi di Geografia, 63, 53-67.

CREMONINI S. (2009) - *River-sea relationships in the Northern Adriatic sea at the beginning of the L.I.A. Insights and suggestions from Po River delta coastline before the year 1604 (Porto Viro Cut)*. Communication held at the National Meeting «Il sistema fiume-costa», Ferrara, June 27$^{th}$, 2008.

DOCCI M. & MAESTRI D. (1984) - *Il rilevamento architettonico: storia, metodi e disegno*. Laterza, Bari, 323 pp.

FABRI O. (1598) - *L'uso della squadra mobile con la quale per teoria et pratica si misura geometricamente ogni distanza, altezza e profondità, s'impara a perticare, livellare et pigliare in disegno le città, paesi et provincie*. Venezia, 60 sheets (= 120 pp).

GABBIANELLI G., DEL GRANDE C., SIMEONI U., ZAMARIOLO A. & CALDERONI G. (2000) - *Evoluzione dell'area di Goro negli ultimi cinque secoli (Delta del Po)*. Studi Costieri, 2, 45-63.

MALAFARINA G. (2005) - *La Galleria delle Carte geografiche in Vaticano*. Panini, Modena, 156 pp.

MARINELLI G. (1881) - *Saggio di cartografia della regione veneta*. Regia Deputazione di Storia Patria delle Venezie, Venezia, 980 pp.

MARINELLI O. (1924) - *Le curiose vicende del delta del Po*. Le Vie d'Italia, 30 (4), 353-362.

MILLIGAN T.G., HILL P.S. & LAW B.A. (2007) - *Flocculation and the loss of sediment from the Po River plume*. Continental Shelf Research, 27, 309-321.

PETRELLA M., SANTINI C. & TORRESANI S. (2006) - *Geografie di un territorio. Studi e ricerche per un dizionario storico dei cartografi in Emilia-Romagna*. Patron, Bologna, 188 pp.

ROMANELLI G. (2004) - *Cristoforo Sorte: Corografia dello Stato Veneto in cinque mappe*. In: Cantile A. (Ed.), «Il territorio nella società dell'informazione: dalla cartografia ai sistemi digitali», Istituto Geografico Militare Italiano, Firenze, 35-40.

SALGARO S. (2006) - *Cartografi e cartografia come strumenti di controllo e gestione territoriale nella Repubblica di Venezia*. In: Valerio V. (Ed.), «Cartografi veneti: mappe, uomini e istituzioni per l'immagine e il governo del territorio», Editoriale Programma, Padova, 33-44.

STELLA A. (Ed.) (1911) - *Delta del fiume Po. Stato alla fine del 1886 con indicazione delle variazioni subite dal 1530 in poi*. Carta alla scala 1:100,000, (1887), Regio Ufficio Geologico d'Italia, Roma, 1 sheet.

TAMBA G. (1970) - *Il Taglio di Po a Porto Viro*. In: (without Eds.), «Mostra storica della Laguna veneta», Stamperia di Venezia, Venezia, 129-131.

TANABE S., SAITO Y., SATO Y., SUZUKI Y., SINSAKUL S., TIYAPAIRACH S. & CHAIMANEE N. (2003) - *Stratigraphy and Holocene evolution of the mud-dominated Chao Phraya delta, Thailand.* Quaternary Science Review, 22, 789-807.

TANG L., CROVELLA M. (2004) - *Geometric exploration of the landmarks selection problems.* In: Barakat C. & Pratt I. (Eds.), «Passive and active network measurement», Springer, Berlin, 63-72.

TIMAR G., SZEKELY B., MOLNAR G., FERENCZ C., KERN A., GALAMBOS C., GERCSAK G. & ZENTAI L. (2008) - *Combination of historical maps and satellite images of the Banat region. Re-appearance of an old wetland area*. Global Planetary Change, 62, 29-38.

TUMIATTI A. (2005) - *Il Taglio di Porto Viro: aspetti politico-diplomatici e territoriali di un intervento idraulico nel delta del Po (1598-1648)*. Grafiche Diemme, Taglio di Po, 356 pp.

VAGNETTI L. (1970) - *Cosimo Bartoli e la teoria mensoria nel sec. XVI*. Quaderni dell'Istituto Elementi di Architettura e Rilievo dei Monumenti di Genova, 4, 111-164.

ZUNICA M. (1974) - «*La bonifica Delta-Brenta*». *Un esempio di trasformazione del paesaggio nella laguna di Venezia*. Rivista Geografica Italiana, 81 (3), 5-60.

*(Ms. presented 1 April 2009; accepted 15 October 2009)*