Marco Piccardi*

Small, Medium and Large Scale Maps in Coastal Studies.
What Happened to Arno’s Mouth between the XIVth and the XIXth Century?

Keywords: Arno river; Pisa - Livorno plain; historical cartography; coastal dynamics; historical hydrography

Summary: An ever growing number of experts and specialists in modern territorial evolution use historical cartography as a primary source. We can say the same for those interested in the evolution of a coastline, not necessarily from an historical point of view, but because they are engaged in counteracting what appears to be an un-restrainable phenomenon of erosion that in 2006 concerned 42% of the low sandy beaches of the Italian coast. We do not have to go too far back in time to see that the intermittent phenomena of an advancing and retreating coastline is not new. Compared to a century or two ago, however, erosion today not only causes severe and immediate economic repercussions, but in the short and intermediate time frame risks the same repercussions on population distribution and settlement at both a national and regional level. Naturally this is all due to global factors: climate change, rising sea levels, greenhouse effect, and others.

Few negationists are left, but the panorama of hypotheses on the causes of climate change, especially when we limit the area of investigation, will continue to grow. This is also because not all low Mediterranean coastlines react in the same manner to the same solicitations. In the case of Tuscany, different reactions may be visible in areas distant only a few kilometers from one another, and sometimes only a few hundred meters. Geo-environmental factors such as subsidence, tectonics, sea currents; anthropic factors such as deforestation, land fill, river bed quarrying and canalization, harbor construction, and the remedies adopted to stem the effects of the above: all contribute to differentiate the coastline’s response.

Beginning with the latest medieval period, anthropic factors can be studied with some possibility of success and correct interpretation, even though they are sometimes unpublished and only available in historical archives. Here we can discover the exact (or almost) date when a harbor or breakwater was built, a meander cut, a river mouth moved. And from a climatic viewpoint, limiting ourselves to rainfall, even though reliable figures lack for the more distant centuries, we have a fairly complete record of the more important floods that indicate periods of incessant rainfall.

It is therefore important to thoroughly study the evolution of a specific section of coastline. Over the last five centuries, historical cartography has become an exceptionally useful instrument in research using integrated sources – descriptive, historical hydrographic essays, chronicles, and so forth.

In the following pages, synthesized as deemed necessary as an extract of a more lengthy study in print¹, we will examine the accretion and erosive phases of the mouth of the Arno River, the fourth longest Italian river and the longest in Tuscany, from the XIVth century to the last quarter of the XIXth century. These pages will also offer an initial overview of the data regarding the sedimentary surplus that influenced an area of six kilometers to the left and right side of the river mouth: San Rossore, a natural park almost without settlements, to the north, and Tombolo with the tourist towns of Marina di Pisa and Tirrenia, heavily urbanized during the last century, to the south.

* Independent researcher. Department of History, University of Siena, Department of Earth Sciences, Department of Historical and Geographical Studies, University of Florence, Italy [m.piccardi@tin.it]

¹ This study, limited here to the Arno River mouth between XIV and XIX century, is understood to be only a part of a larger study which will encompass the physiographic unit that extends from Viareggio to Livorno to XIV and XXI century.
The evolution of a shoreline: the documentary value in cartography and iconography of the past

An excellent heritage in historical cartography is available for Tuscany, and a large part of this is dedicated to the Tuscan coast and archipelago (Guarducci A, Piccardi M., Rombai L, 2012). Among the coastal areas, the Pisa to Livorno plain was the most intensively mapped area in the Medicean and Lorraine state's administrative graphics production (Guarducci A, Piccardi M., Rombai L, 2009). Upon examination of this patrimony and beginning in the XVI\textsuperscript{th} century, we observe the last three centuries of a continuous phase of littoral advancement which began approximately from seven to five thousand years ago (Dall’Antonia B., Mazzanti R., 2001, p. 8), and the first two centuries of a phase of littoral retreat, the latter most probably destined to continue for the next decades. Understanding the dynamics of the littoral surrounding the Arno River mouth and discovering the precise moment when accretion slows and ceases and erosion begins will allow us not only to limit local anthropogenic and/or climatic factors, but may also supply a useful reference point for the catastrophic projections referring to the future of our coastline.

The mouth of the Arno River, where our investigation takes place, is located inside a littoral zone characterized by a low sandy coastline that begins at the Tuscan border with Liguria and extends south for more than 60 kilometers to Livorno. The river mouth acts as a natural border between the Migliarino San Rossore Natural Park (an area almost completely without settlements), and the urban and highly touristic seaside towns of Marina di Pisa and Tirrenia.

![Figure 1: Location map of the study area.](image)

The available reliable data referring to rising sea levels, subsidence and tectonics by themselves cannot explain the interruption of the coast's accretion and subsequent erosion, the latter evident since the second half of the XIX\textsuperscript{th} century. Accretion and erosion are therefore intermittent events that, among natural factors, are caused by wave currents and climatic elements (specifically the Little Ice Age, though with many caveats is usually thought to have run from the middle of the XVI\textsuperscript{th} century until the middle of the XIX\textsuperscript{th} century). Here we are dealing with two natural factors
that are fairly sensible to anthropogenic influences: just bear in mind the building of breakwaters (at Livorno, the most important breakwaters were begun in the second half of the XIXth century), seawalls, and more in general, the greenhouse effect.

While observing clearly anthropogenic events, the usual instruments are archeological and historical, yet from the beginning of the XVIth century it is cartography that gives us the best overview and the most representative indications of coastal evolution. This becomes ever more precise as we gradually proceed from very small to very large scale maps. The most useful markers present on these maps are first, the positions over the centuries of military defenses along the littoral (especially the costal towers, always near the sea where they fulfilled their primary functions as multifunctional structures dealing with health and contraband, and less often, as aids to river navigation (Guarducci A, Piccardi M., Rombai L., 2013, in print), then the ridges that may indicate the previous position of the coast (Pranzini E., 2007), along with the hydrographical network and reclamation works, and land use.

For the previous centuries, we can observe the very small scale used in the medieval nautical charts (the only maps able to represent the Mediterranean and Atlantic coasts during the XIVth and XVth centuries, where we must acknowledge that the information garnered will be extremely limited with respect to more recent maps, and above all, unable to tell what really happened immediately behind the coastline or at the river mouths (Lepore F, Piccardi M., Pranzini E., 2011).

Figure 2:. The Arno River from Pisa to the sea in 1338 (sky blue), 1606 (blue) and after the 1607 straightening of the mouth (pale blue). The three towers that mark the evolution of the delta with the S. Rossore and Vettola meanders (cut in 1338) and the Barbaricina menader (cut in 1770-1774).

Beginning with Leonardo da Vinci’s 1503 map (Figure 3), despite its small scale, we begin to have the first useful indications on the coastal position at the beginning of the XVIth century. The map completely covers the Pisa - Livorno plain and the last 45 kilometers of the Arno River’s course where there are still evident the numerous and ample meanders that have now in part disappeared (Figures 2 and 3). As we will find in Figures 11 and 25, respectively two and three centuries later, Leonardo’s map clearly illustrates a river delta defined by a sandbar that splits the mouth in two. Other territorial elements positioned by Leonardo are the Torre della Foc (today known as Torretta), and the road from Pisa to Livorno that passes through San Pietro a Grado with its Roman Basilica. It is believed that the first church was built in the IVth century very close to the coastline directly over a Roman landing place. This is the position of the church in the
graphic reconstructions that accompany the ample literature dedicated to the reconstruction of littoral dynamics in the Christian era.

Figure 3: Leonardo da Vinci (1503). The Pisa – Livorno plain.

Many of the hypotheses regarding the coastline’s position before the modern era must still be fully confirmed despite comparisons with archeological sources, the analysis of satellite imagery (Pranzini E., 2007), and the attention dedicated to ridge patterns (Kukavcic M.; E. Pranzini, 2003). Comparative and retrospective research of historic iconography therefore allows the relatively precise placement of the coastline at the time of one of the most important operations undertaken on the last stretch of the Arno River: the 1338 cutting of the meanders. Referring again to the 1503 map, we must note that the two arms of the river mouth emphasize the delta, showing both the protuberance of the right lobe and the retreat of the northern littoral: an element that is anything but casual.

The same is evident in an anonymous map referring to the Pisa - Livorno plain from the years 1554-1564 (Fig. 4). As we can see here, a sizable increase of the delta, a distinct crescent shape between the Arno and the Serchio and the pronounced right hand Arno lobe are all quite evident, with the latter confirming the reasoning behind (and minor expense of) the 1607 cutting of the river mouth. According to Fiaschi (1938, page 158), while referring to a document dated 1579, the mouth of the Arno was a mile wide: a reasonable value for the time. The distance is coherent with the value given in Figure 4, defining the position of the mouth and the coastline thanks to the positions of San Piero a Grado and Torretta, along with the drawings of the ridges and the position of the San Rossore meander.
The positions of *Torre della Foce* and *Torretta* in the 1503 map appear to be much closer to the right bank of the Arno than from the measurable distances indicated in a drawing from 1606 (Fig. 8). This would make us suspect a shift (or more probably, a narrowing towards the north) of the end of the riverbed.

Figure 5. Alternating ridges and interdune swales and their relationship to the coastline between the XVIth and XVIIIth centuries.
Not only the passage of time increases refinement in drawing the maps and guaranteeing their increased reliability. If we were to look at the most famous landmark map of Tuscany at the beginning of the XVIIth century, the Giuseppe Rosaccio map (dated 1609, reprinted in 1662, Figure 6), and the Dominio Fiorentino map by Gio Antonio Magini (published in 1620, Figure 7), it is difficult to recognize both the Barbaricina meander (cut between 1770 and 1774) and the deviation of the river mouth, the latter being the most important operation from the beginning of the XVIIth century to the present. This operation, by taking advantage of the curve and protuberance of the right hand lobe illustrated in Figure 4, brings the river mouth 1500 meters more to the northwest of the original mouth, and shortens the last tract of the river by the same distance.

![Figures 6 and 7: The Pisa-Livorno plain in the Tuscans by Giuseppe Rosaccio (1609) and Gio Antonio Magini (1620). Details.](image)

In the attempt to improve river navigation and resolve the problems of flooding in Pisa, in 1606 the project of straightening and moving the Arno River's mouth was defined (Fig. 4). Oriented to the southwest, it was completely open to the predominant south (scirocco) and southwesterly (libeccio) winds. The project, undertaken by the architect and engineer Cosimo Pugliani, closed the existent mouth (known from then on as the Arnaccio or Old Arno, Fig. 14), and dug a new riverbed orienting the river mouth to the west.

In our reconstruction, strikingly enough, it is the very simple Figure 8 that will be extremely useful. The Old Arno path is perfectly visible both in present day satellite images (Fig. 10) and in the XVIth and XVIIth century maps, when with rapidly increasing accuracy they defined the evolution of this portion of the littoral (Figures 8 to 11). An example is the 1780 farm map of the Nuovo Podere della Torre del Arno Vecchio, drawn almost two centuries after the original cut (Fig. 9). We will return to this map later, as it guarantees an accurate confirmation of the measures given in the sketch of 1607. The linear measurements in Figure 8, confirmed and elaborated in a report by Pugliani, when compared to Figure 4 from the middle of the XVIth century and with the ridges in the Lidar images (Fig. 23), allow us to define the coastline in 1607: to the north the river mouth is aligned with the Cotone del Ginepro and to the south with the lower border of the Cotone delle Paglie. This measured distance referring to the river mouth before the 1607 cut (together with calculations referring to a symmetric waterway, the Vannini Canal, in the northern littoral) represents an important reference point in our reconstruction calculations.
The river mouth shouldn't have remained unprotected for long, yet we had to wait until 1682-1684 for the construction of the Torre Nuova di Bocca d'Arno (Figure 9), located where before the moving of the river mouth was the right lobe (now the left lobe). This tower was abandoned shortly thereafter due to the rapid growth of the river mouth and will end up as part of one of the earliest farmhouses at Bocca d'Arno. The tower's exact position today represents another perfect reference point for measurements in the otherwise extremely scarce number of buildings that were present in the Tombolo and San Rossore areas up until the XXth century. The 1606-1607 project had a difficult time: cutting part of the right lobe, the mouth was then aligned with the northern coastline while on the southern bank the littoral overtook the left lobe by about 1500 meters. The almost perpendicular cut near the mouth, with an almost nonexistent gradient, caused the lengthening of the river and the forming of a sandbar in front of the mouth. All this is illustrated in the aforementioned 1681 map of the Pisa - Livorno plain by Francesco Gaeta (Fig. 11).

In Figure 11, the Arno River mouth is over two and a half kilometers wide and traversed by a sandbar leaving one mouth to the north and one to the south. The southern mouth was aligned with the Old Arno mouth where the littoral had advanced by about one hundred meters. The bar across the funnel shaped mouth recreated a transitory situation of two river mouths. For the next two centuries, the Arno and marine currents do their best to bridge the mouths, while an exceptional quantity of sediments quickly fill the new mouth. Taking advantage of the weak resistance of the unconsolidated new ground of what was the old right lobe, the river dug a new mouth oriented southwest, parallel to the old mouth.
Figure 9: Giovanni Caluri (1785). Old Arno’s mouth in the *Nuovo podere della Torre di Arno Vecchio* map. Detail.

Figure 10: Coastline in the XVI\textsuperscript{th} (green and red) and beginning of the XVII\textsuperscript{th} century (brown). Old (dashed) and new mouth in 1606 with the *Torre Nuova di Bocca d’Arno*. Detail.
At the end of the XVIIth century, we therefore find a littoral on the left bank that tends to fill the remaining area between the old mouths and the new, to then continue parallel to the coast as it was at the beginning of the century, at a distance of apx. 100-150 meters (Figures 12 and 13). To the north, the coastline stands at the first of the converging ridges that can still be seen below the Ginepro ridge. This ridge, the first of a numerous series of crescent ridges that still define the part of San Rossore near the sea, is part of the typology that Pranzini (2007, p. 406) uses to distinguish the dune systems that originate in response to an intense and rapid sedimentary input: “when material accumulates at the river mouth and does not have time to reach the most distant coastal segments”. Figures 12, 13 and 23 should clarify and confirm our reconstruction. The northern
coastline, before the 1606 cutting, follows the last of the significant ridges that run parallel to San Rossore (il Ginepro). The sudden and ponderous forward movement generated by the cut is visible in the formation of the first crescent ridges (the Code), that continue at a greater distance from one another. The distance between the later western ridges decreases gradually giving rise to a tighter yet less curved pattern, allowing us to suppose that the rhythm of accretion diminished. Confronting the situation as it stood in 1681 with the measurements furnished by Pugliani for 1607 indicate a progradation of the mouth of at least 1,500 meters, the equivalent of about 19 to 20 meters per year.

![Figure 12](image12.png)

**Figure 12.** Old and new Arno River mouths in the XVIIth and XVIIIth century.

![Figure 13](image13.png)

**Figure 13** Crescent and parallel ridges in San Rossore. Detail.

As we can see in Figure 14, the river mouth continues to change at a high rate, overlapping the contents and measurements in a contemporary study by Marco Alessandro del Borro (ASF, SRPP, 3550,c. 37), dating from the years bridging the XVIIth and XVIIIth centuries.
Figure 14: Anonymous (early XVIII\textsuperscript{th} cent.). The Arno’s mouth with orthogonal interdune swales.

In figure 14 the huge sandbar that occluded the mouth as it was in 1681 seems to have attached itself to the southern littoral, leaving traces of the southern river mouth in the three orthogonal swales and ridges that are plainly visible on the left lobe next to the Old Arno. From this point, the Arno runs north for about 2,500 meters, defining the well advanced limits of San Rossore (some of the superimposed figures of the points that we chose for our measurements show the elementary method we used to determine the calculations and linear pre-geodetic reconstructions). The reconstruction shown in Figure 12 examines the maximum expansive phase (1607-1769) that gave birth to the last of the curved ridges, the Ontanelli and the Mare. On the seaward side the point of the Ontanelli ridge is oriented southeast, while the Mare southeast by east. These indicate the orientation of two very short lived mouths and the progressive southern shift of the Arno River mouth. Today both ridges are submerged, at least as far as 2,000-2,500 meters north of the mouth.

After 1769, discarding the probable short peak periods, littoral accretion continues but at a slower rhythm. Notice must be taken however of the right lobe, which since the beginning of the 1700's has overtaken the present day coastline. We are therefore dealing with an evolutionary process in rapid and constant mutation that will soon bring the Arno to carve the long line that appears in Figure 14.

A large scale map from 1759, preserved at the Haus-, Hof- und Staatsarchiv in Vienna, gives us an almost straight river mouth (Fig. 15), to be inserted among those now obstructed as illustrated in Figure 11. There is still a high rate of progradation at the river mouth: once more, the Torre Nuova di Bocca d'Arno allows us to measure an accretion of apx. 1,000 meters in sixty years (13 to 14 meters per year). The lobe is now very near to the still submerged location where within a few years a new fort will be built, about 1,800 meters from the Torre Nuova. The fort's foundations were still easily discerned in aerial photography taken a few years before the beginning of the construction of the improbable Marina di Pisa tourist marina harbor (Fig. 16).
Since then, discovering the precise date of construction and position of the two fortifications commanding the mouth of the Arno has allowed us to be even more precise in the measurement and verification of the preceding estimates.

Figure 15: Admant (?) (1759). The distance from Torre Nuova to the sea (detail with graphic scale).

Figure 16: The left lobe between 1759 and 1769 (Figures 15 and 17 respectively)

Constant accretion of the river mouth causes the erosion of the unstable right bank of the Arno, so recently won from the sea. The river, accumulating sediments along the right bank, narrows the mouth and erodes the left bank (Figures 17 and 18). The maps from the 1700's confirm the progressive and natural east-west reorientation of the river mouth, almost completely done by the middle of the XVIIIth century.

The 1770-1774 cut of the Barbaricina meander was carried out immediately after Niccolo Stagi (or Stassi) drew the map depicted in Figure 17 on the 8th of June, 1769, showing the fort less than seven years from its construction at a position 270 meters from the apex of the left lobe. Using Figure 15 for the position of the Torre Vecchia, the river mouth has advanced by 500 to 550 meters in ten years, at a rhythm of 50 to 55 meters per year.
To broaden our horizons beyond the limited area of the Arno river mouth and place the situation in the more ample context of the territorial realities from the middle of the XVIIIth century to the middle of the XIXth century, we can turn to two exceptional maps of the Pisa-Livorno plain: the 1769 map by Ferdinando Morozzi (Fig. 19), and the 1830 map by Giovanni Inghirami (Fig. 20). With the relative ease of access to these maps, and the ample area covered by them, we normally turn to them to reconstruct the coastline. But it must be said that they may hide pitfalls that may affect the reconstruction of littoral elements. In the pre-geodesic 1769 map there are toponomastic inaccuracies that may cause errors in calculation. One example is the Fortino di Bocca d’Arno, identified as Torre, the same as we noticed almost two kilometers inland; another a Torretta in an incorrect location near a mouth of the Old Arno that appears to open directly to the sea.
The Inghirami map, useful to us for its increasing bathymetric information the closer you come to the coast, is properly considered an authentic monument in Italian cartography. Its small scale however limits the representation of territorial elements: for example, *Torre Nuova di Bocca d'Arno* and *Torretta*, essential for our reconstruction of the coastline, disappear, along with a large part of the toponomastics for the interdune swales and ridges. In any case, these small scale maps, while necessary for a more complete vision of an area, when dealing with the definition of precise estimates of costal phenomena tend to reveal some inadequacies, if nothing else because of length of time necessary to update and perfect the cartographic technique that is less central to large scale maps.

With the exception of the Bufalotti curve, the 1770-1774 Barbaricina cut ensures that from then on the Arno runs in an almost straight line from Pisa to the sea. The cut shortens the river course by 1,000 - 1,100 meters, and after four and a half centuries allows us to examine the behavior of the river mouth after the cutting of one of the meanders. Unexpectedly, the accretion of the river mouth at the northern lobe notably decreases, at least for the moment. Comparing the two twin maps from 1769 and 1822 (Figures 17 and 18) that concentrate on the Fortino di Bocca d'Arno, we are able to establish that in 53 years the apex of the lobe has advanced by about 200 meters, at a rate of a little less than four meters per year: in the following years the rate will slow even more. Given these preconditions, the southern littoral advanced for no more than 350/400 meters (2 to 2.2 meters annually) from 1607 to 1780, and if we use reference data from the intermediate period from 1681 to 1700 (together with those derived from the 1759 and 1769 maps), this rate of littoral accretion must have remained constant for the complete period of observation. This corresponds to a much more substantial accretion of the river mouth: approximately 2,400 meters (but not at a
constant rate), at almost 19 meters per year. The evolution of the northern shore is quite different, and we can use the 33 tavole from the Cabreo of the Coltano and San Rossore holdings, conserved at the Scrittoio delle Regie Possessioni at the Florence State Archives. These figures are dedicated to the land usage and buildings present on the Grand Duke's holdings, with maps, views, cross-sections and plans.

Figures 21-23. Giovanni Caluri (1785) and LIDAR airborne survey. San Rossore: the Mare and Ontanelli ridges, the crescent shaped code, the Vannini Canal (detail with graphic scale).

In what was a large delta a century before, we now see the reclamation endeavour of a large littoral area, with systematic attempts to give order to and consolidate the land. Before 1785 a new canal was dug, known as the Vannini Canal in subsequent maps. This canal took water and sediments from the Arno from just after the San Rossore meander and entered the sea after having cut across the Ontanelli and Mare Ridges. The ruler straight canal, whose last 1,200 meters today ties into the Cateratte Canal, tellingly match 5,000 Braccia (about 2,900 meters, Fig. 22): the
length of the graphic scale. The canal still exists today, as it can easily be seen, together with the crescent shaped ridges (Fig. 23), in the superimposed Lidar airborne image. The imminent move to geodetic mapping (land registry maps from the second and third decade of the XIXth century, and the IGM maps in 25,000 scale from 1878, 1881, 1907, 1928, 1939, and 1954) and then satellite imagery have allowed us to create very reliable sequences. Of course these maps also guarantee an excellent reference point for the past centuries.

We are then able to calculate that the accretion of the coastline along the reference line indicated by the Vannini Canal between 1607 and 1780-1785 (with symmetrical accretion in the southern littoral as much as 350-400 meters) is of approximately 2,000 meters. That would be an annual average of 11.5 meters, but given the situation that we have already seen in Figure 14, we can hazard a guess that from 80% to 90% of that measurement was reached at the beginning of the XVIIIth century. This measurement is coherent with the data from a 1840 map conserved in Prague that contains specific elements dedicated to monitoring coastlines (Figure 24). This map is notable for its coherent representation of multiple territorial elements, and dedicates considerable attention to interdune swales (and indirectly, ridges), while placing three termini (landmarks) near the coastline: in front of the new fort at Bocca di Serchio, at the Gombo Tower, and on the coast at about 500 meters from the right river bank. This not only tells us that, at least in 1829, the coastline was perceived as growing, but that it was also recognized that eleven years later and at the southernmost termine, there was a progression of about 70 meters. It is also worth considering the continual narrowing of the river mouth, from the greater width as shown in Figure 4, to little more than today's 100 meters.

The 1:28,800 scale topographical map of the Compartimento Lucchese by Celeste Mirandoli covers the Pisan plain in the middle of the XIXth century, and exists in two versions. The 1850 version is held in Florence (IGM, Cartografico, http://www.igmi.org/ancient/scheda.php?cod=6610), while the other, from 1857, is conserved in Prague (Fig. 25). Commissioned by the Ministry of War, and with the participation of Adolfo Zuccagni Orlandini, the map is divided into 26 sheets mounted on canvas. Celeste Mirandoli worked with the triangulations done by Michele Bertini between 1830 and 1843 in the Duchy of Lucca. Among the elements present in the map,
we find the Casa dell'Acqua: located at the top of the triangle created by the Stradone delle Carrozze and the present day Canale delle Cateratte, between 1939 and 1954 it was submerged because of riverbank erosion, and later repositioned about 50 meters to the north of the original location. Today the Casa dell'Acqua is about 40 meters from the shore, but in 1840 it stood at about one kilometer from the apex of the northern lobe, and about 850 meters from the point where the southern landmark was placed in 1829. Once again, an extremely long sandbar formed across the river mouth. The southern lobe, unlike the right lobe (and unlike its present day shape), was farther back and less pronounced, this makes us suspect the precarious rise of the sandbar shown in Figures 26 and 27.

Figure 25: Celeste Mirandoli, (1857). Arno’s mouth with the lengthy sandbar. Detail.

Figures 26 and 27. John Knight (1795), Bourguignon Duperré et Begat, (1852, survey 1846). Nautical charts, soundings and shoal water near the Arno River mouth (details).

In the meantime maps of the sea evolved from the medieval portolan charts to modern nautical charts, and therefore become more useful to us, with their increasing use of bathymetrics. The first
modern charts for Tuscany appeared towards the end of the XVII\textsuperscript{th} century. Here the soundings were limited to the areas adjacent to the coast, and more specifically, to harbors, ports, and river mouths. The first charts were produced by the great European maritime powers of France and England, and later, when the Granducato began to autonomously produce its own charts, it often turned to the foreign specialists, who sometimes simply repeated their previous works without much updating.

The precise contribution that nautical charts can give to reconstructing coastlines becomes evident when consulting John Knight's 1795 \textit{the chart of the Road of Leghorn}. In Figure 26 the shallows to seaward of the northern lobe encircle the southern lobe showing an erosive phase of the latter that is rather perplexing. In the details extracted from two sheets of the \textit{Carte particulaire des côtes d'Italie} made for the Dépot generale de la Marine in 1846 (Figures 27 and 29), the delta's situation appears to have changed: shoals have emerged in front of the lobes and their probable sudden rise may explain the “bateau échoué” in Figure 29. Looking at nautical charts therefore, the reasoning behind the updating and progressive refining of the coastline in small scale terrestrial maps becomes clearer, and new factors that can compromise their precision come into play: the difficulty in both having a sufficient number of soundings and their exact positioning, the variations of magnetic north, the ever changing depths of the seafloor near the coastline, to name just a few.

Despite this, a comparative analysis using present day soundings (Fig. 28) evidences a progressive and consistent deepening of the sea floor along the coastline. We must note here that the phenomenon, recorded in previous studies regarding the Arno River mouth, is not traced to a rise in the sea level (or, more specifically, the rise in the sea level is very limited in respect to the effects of erosion and sediment redistribution along the coast).

During the last quarter of the XIX\textsuperscript{th} century, after a slowdown in the accretion rhythm that first affected the northern littoral, and then the river delta, erosion began to attack the lobes. Thanks to the 1:25,000 scale maps by the Istituto Geografico Militare (and especially the historic series of updates continuing to this day), the erosive phase has been successfully measured and studied in manifold publications, even if the interpretations of the causes do not find everyone in agreement. The use of aerial surveys and the diffusion of satellite imagery have rendered the monitoring of the coastline ever more reliable.

Conclusions

The first result of this article has been the correction of the widespread opinion that reliable cartography began in Tuscany with the first geodetic land survey maps from the beginning of the XIX\textsuperscript{th} century. Comparative analysis of large and very large scale maps produced during previous centuries, integrated by descriptive sources, demonstrates not only the high reliability of scale and linear measurements that were obtained simply by walking and measuring the ground with \textit{braccia}, \textit{canne} or \textit{pertiche}, but also the superior information content regarding the landscape and the environment, accompanied by a more rigorous topographic content with respect to small scale maps.

Concluding, in an extreme synthesis, and referring once again to a wider study that will soon be published the research, conducted using a considerable number of diachronic and synchronic maps, has obtained the unexpected result of calling into question certain data and subsequent interpretations that were previously diffused regarding the evolution of the coastline in modern times. We are dealing with the fine tuning of the hierarchy of natural or anthropogenic phenomena that have already been included as causes of either accretion or erosion, that the available space has not allowed us to develop.

Acknowledgement

These pages are the result of revisions and suggestions by Enzo Pranzini and Leonardo Rombai. The author however maintains sole responsibility for the contents. Sincere thanks to Fortunato Lepore for the graphics and to James Robinson Taylor for the English translation.
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