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## Historical cartography and coastal dynamics of the Apuan littoral in the modern and contemporary periods: the port of Marina di Carrara (Tuscany, Italy)

Keywords: historical maps, coastal dynamic, Apuan coast, Avenza, Marina di Carrara

*Summary:* Along the northwestern Tuscan littoral, using 18th to 20th century cartography together with reports from specialists and engineers, we can reconstruct the costal dynamics, environmental evolution and organization of the territory - the marshland recovery and agrarian colonization of the lowlands and the construction of the two simple docking facilities serving the towns of Avenza-Carrara and Massa. Since the late medieval period this area belonged to the Malaspina Principato, later the Cybo Malaspina di Massa Carrara, and from the 1730's until 1859 to the Este Duchy of Modena.

For many years the littoral's only seaports were the problematic havens at the mouths of the Magra, Carrione and Frigido rivers. The littoral was almost completely uninhabited until the construction plan for the port of Avenza (now known as Marina di Carrara) was undertaken. The history of this Italian port is well known, having the dubious honor of the longest period between initial planning and final completion: from the middle of the 18th century until the middle of the 20th century. Less well known are the territory's natural dynamics, costal advancement, erosion and wave action.

The study of these records allows us to bring the profound transformations of the Apuan landscape and costal environment between the 18th and 20th centuries to the forefront. At first characterized by littoral advancement and later, from the end of the 19th century until the present, by the littoral erosion that is undermining seaside tourism, the area's primary economic activity. These records also allow us to better understand the processes behind these transformations and to formulate plans for their management, in the attempt to reduce erosion without further burdening the coast with rigid defense works.

### The Apuan coast

The long term political and administrative vicissitudes of the Apuan coast were entirely different from those of the rest of central and northern Tuscany, united since early medieval times under the two city-states of Lucca and Florence (with the latter also acquiring the Republic of Pisa in 1406). The Malaspina feudal faction dominated the territories of Carrara and Massa, which up until modern times were made up of small settlements almost completely without the bourgeois governing class that brought growth to Tuscan cities. The territories, which were divided up among the various branches of the Malaspina family, were finally brought together under the government of Duke Alberico I Malaspina in 1442. Almost a century later, in 1521, Riccarda Malaspina married Lorenzo Cybo, giving birth to the Cybo Malaspina dynasty ruled over the principality until the dynasty's end in 1732. Massa and Carrara then became a province of the Duchy of Modena under Ercole Rinaldo d'Este, husband of the last of the Cybo line, Maria Teresa (Giampaoli 1988:39).

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During the second half of the eighteenth century, up until 1829, the Apuan territory maintained a relatively ample administrative independence under the lengthy reign of Maria Beatrice d'Este. The tyrrhenian principate was then fully incorporated into the Duchy of Modena, first under Francesco IV and later under Francesco V d'Asburgo Este. When the dynasty fell in 1859, the Duchy chose, by referendum, annexation to the Kingdom of Sardinia in 1860, prologue to the Kingdom of Italy in 1861.

Under the rule of the Cybo Malaspina (1521 – 1732), the feudal state was transformed into a modern principate, which, from midway through the 16th century, produced important public works such as the urban planning of Massa and the enlargement of Carrara. These two small towns, through the following decades, became small cities containing important architectural monuments. Not surprisingly, this period was also characterized by the production of cartography and documents for the administration of the new State.

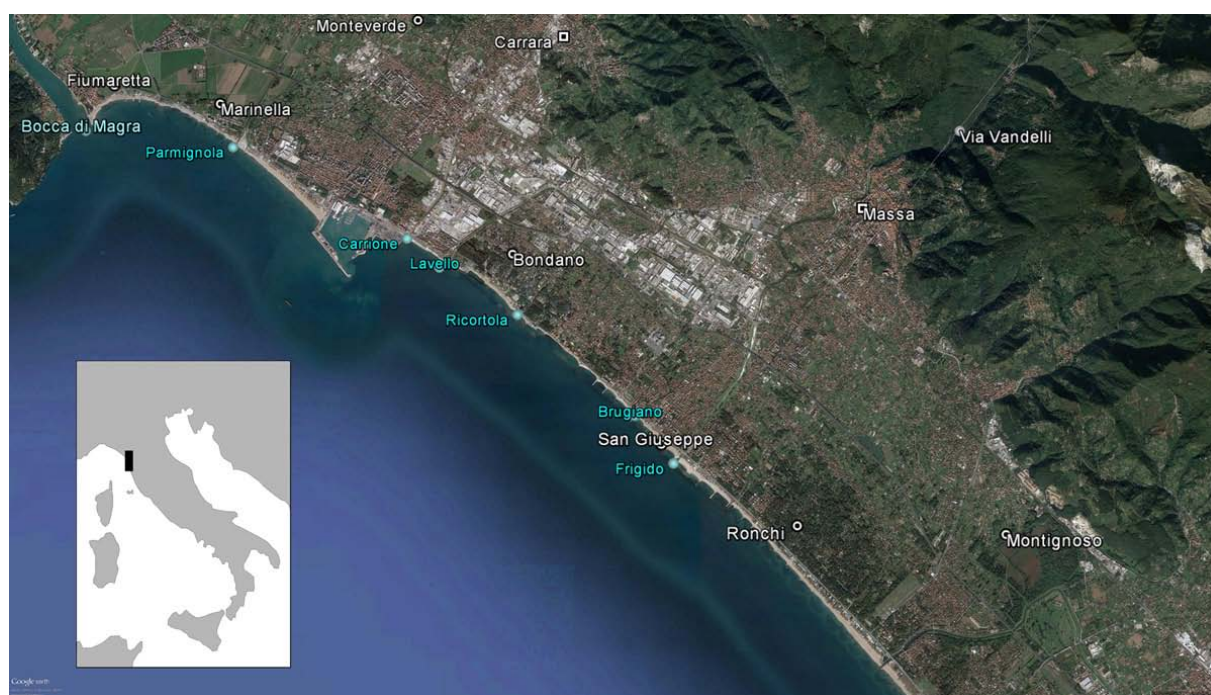


Figure 1: The northern Apuan littoral: hydrography and place names (in GEarth).

The maps and documents produced for administrative purposes by the Cybo Malaspina government in the second half of the 16th century, such as the bird's eye view of Massa with the addition of the marina (AS<sup>1</sup> Massa, Giampaoli 1988:9), show that then the beaches were completely uninhabited. The only exception was the small medieval town of Avenza which, because of progradation, stood ever farther from the coast. Though while in 1565 the fort's artillery beat back a barbarian fleet, during the 17th and 18th centuries the cannons were not able to adequately cover the beaches, leaving the port undefended against attack from the sea (Guarducci et al, 2014). Ligurian fishermen, shepherds, and farmers from the mountainous interior, occasionally inhabited the littorals of Avenza-Carrara and Massa, without any civil or military settlements. Very few were those responsible for the modest administrative duties required by the two landings at the mouth of the Carrione and Frigido Rivers belonging to the principate. But the littoral was the only channel for exporting Apuan statue marble. The area,

<sup>1</sup> AS is the abbreviation of State Archives (Archivio di Stato) used throughout this paper.

from the mouth of the Magra River and the border with Genoa at Marinella di Luni, to the border with Lucca at Montignoso down to Viareggio, was considered a frontier zone. Here the coast served as a port of call for goods and necessities such as cereals and salt imported from abroad, but as an open roadstead was very dangerous to shipping.

Among all the regional and sub-regional scale cartography of the area, several administrative maps are noteworthy, especially the 1765-1790 map of Lunigiana and Apuania, the only map to show the port of Avenza connected to Carrara by road. Marina di Massa is not shown, but the road that connects it to the city is (Guarducci et al, 2012:104). The cartography does not show the unmanaged watershed situation, a feature common to all the Apuan coasts (and its extension towards Versilia and Pisa). The area was characterized by the numerous marshes found in each depression in the ground, especially near the mouths of streams that periodically left their beds. These areas were rich not only in fish but in malaria, a mortal danger to the local populations, especially during the summer months. The marshes at the mouths of the Carrione, Frigido and other minor rivers, especially at the Avenza and San Giuseppe landings, were typical in the environmental history of the Apuan coast and the low-lying areas of Tyrrhenian Tuscany. Until the 19th century these streams, like the Carrione and the Frigido, never fed straight into the sea, but were characterized by torturous and constantly changing or dead-end courses, shifting according to flooding, the action of the sea and the wind. They were unstable openings to the sea, often subject to splitting into two branches when passing through the depressions in the Tombolo, as with the Frigido in the 17th century, with arms that connected the stream to its neighbors, the Magliano and Brugiano. The stagnant waters and ensuing diseases, together with the impossibility to defend the coast from military incursions, explain the absence of a stable local population. Yet the inhabitants of the hillside towns managed to collectively exploit the coastal plain, mostly property of the towns and characterized by uncultivated dry areas and humid pastures, for livestock and, where possible, fresh water fishing. By the 16th century the Apuan coast had already been almost completely deforested when compared to the vegetation present in mediaeval documentation (Leverotti 1982). The littoral running from Pietrasanta to Versilia, until the middle of the 18th century, was covered with oak on the drier ground near the sea and with alder on the lower, more humid terrain behind the dunes.

The first projects regarding the last reach of the Carrione and the Frigido and the drying out of a few small marshes were undertaken in the second half of the 16th century. Success was always temporary however, and renewed attempts to keep the landings efficient characterized the 17th century.

Agrarian use of the coastal plain began in the eastern littoral between the Frigido and Montignoso (near Ronchi – Stradella). The first known map of the area, the 1583 “Drawing to dry the marshes of Massa near the Frigido”, by the engineer Marco Antonio Pasi (AS Modena, Topografia terreni, 28), shows the project to channel the Frigido as it crossed an area partially cultivated with vineyards and including large zones of pagliareti (wetlands with bulrush and reeds, also used for grazing) and the Gorreto Marsh, where farmers from the hillsides and Apuan mountains, under a 1568 perpetual lease from Duke Alberico Cybo, were granted use of the unpopulated, uncultivated and marshy area. Under this lease, a few temporary straw shelters were built; through the years they gradually transformed into huts (Giampaoli, 1988:15).

During the 1580's further perpetual lease projects for agrarian colonization on the plains of Massa and Carrara were stipulated; works included drainage canals, primary tillage and planting trees to shield the cultivated plain from the sea.

Motivation for this expansion soon ran out and complete immobilism set in for the entire 17th century, accentuating the hydrological instability evidenced by the flooding of the Carrione, Frigido and other streams. Even the Serviti convent at San Giuseppe del Frigido was damaged and in 1688 the friars had to move to their new convent at Camporimaldo, close to the city (Giampaoli, 1988:36). Hydrological instability continued throughout the first half of the 18th century.

In 1744 the Estense government issued the “Law and rule above the riverbanks”, creating a tax on the land surrounding the waterways to be improved, and in 1746 created the Magistrato delle Acque. Here began the gradual recovery process of the environment, the economy and the population of the plain of Massa and Carrara; this process stabilized during the second half of the 18th century and throughout the 19th century with the sale of small and medium sized lots and by illegally ousting or occupying the traditional areas used for collective grazing. The engineers of the Magistrato delle Acque began to canalize the rivers and their mouths to improve port construction: to assure long lasting results these projects necessarily were themselves long lasting. In 1765, at the mouth of the San Giuseppe the sediment from the Magra River had blocked the mouth of the Frigido and the ensuing floods had created “a rather large swamp that ran lengthwise, almost parallel, to the coastline”. This swamp rendered the landing difficult to use and increased malarial morbidity among the population. In 1769 the engineer Filippo del Medico unsuccessfully proposed the draining of the swamp by creating a canal to the sea, and equally unsuccessfully tried for years to eliminate the marshes by means of artificial filling (documented by the 1778 topographical map drawn by del Medico), finally completed in 1781 (Giampaoli, 1988:53-60). Fortification of the littoral was also unsuccessful in this period.

New local laws were issued during the 1770’s and ‘80’s regarding the communal lands on the plain with the usual obligations for the farmers to cultivate primarily vegetables and plant pine, oak and alder trees along the coastal strip. Here reforestation, at least in the short term, did not produce particular results. Agrarian projects did however, from the highlands often right down to the beaches. This success “could not but impress, above all, the foreigner, for the care taken of the crops and the fruits they gave”. The engineer Giovanni Attilio Arnolfini, a visitor in 1781, wrote that the farms, even those next to the sea, were well maintained, properly built and full of beans, maize and other vegetables. Another positive impression was that of Lazzaro Spallanzani in 1783: “The western littoral, between the Brugiano and the Lavello, was more limited in its agricultural development as a large part of the area was set apart for communal grazing, primarily cattle.” (Giampaoli, 1988:75-84).



Figure 2: The Avenza and Marina di Massa littoral, detail from the 1778 Filippo del Medico map (AS Modena, Fondo cartografico, Territorio, 168).

The large scale Mappa del Littorale delli Stati di S.A.S. di Massa e Carrara, drawn by the engineer del Medico in 1778 (Figure 2), realistically maps the Apuan coast and confirms the location of two small forts, one on the shore in Avenza and the second at the mouth of the Frigido. Filippo del Medico properly distinguishes the agrarian terrain, made up of small, four sided fields, often bordered by trees, sown with cereals or as open fields, that occupied the plain behind the sandy tombolo, from scattered wetlands covered by low scrubs (Ginepri is legible on the left), with occasional inroads of cultivated ground (Guarducci et al, 2012:104-105).

This landscape without farmhouses is also clearly presented in the August 1777 map by Paolo Vinzoni., it also shows the planned banking of the Parmignola watercourse, located on the border between the two States (Figure 3): the agricultural area with sown fields and trees can be clearly distinguished. At the beginning of the 19th century, nine wetlands were still listed on the coastal plain between Avenza and Montignoso (including San Giuseppe, Lago della Fiora or Brugiano, and Lago di Porta). Health conditions worsened, with an upsurge of epidemics and mortality, especially in Massa between 1807 and 1809.

The 1802 Carlo Giosuè Mansuelli Mappa della Spiaggia del Mare delle due Comuni di Massa e Carrara, property of Mr. Giampaoli, shows the location of four separate military posts, built by the Duchess Maria Beatrice around 1794. They are: the two Avenza batteries, one to the left, the other to the right of the landing, with warehouse, customs house and landing at the mouth of the Carrione; the battery to the left of the mouth of the Frigido or San Giuseppe Landing, and the fourth battery in the area now known as Marina di Ronchi (Giampaoli, 1988:87).

It wasn't until the Estense Restoration that Maria Beatrice ordered the straightening and the re-banking of the Frigido and other rivers (these works were carried out from 1817 until 1827) and the draining of the swamps and pagliareti (from 1821 until 1827-28 and again during the following two decades). To deal with the increasing population during the Restoration, after reclaiming the San Giuseppe and Bondano areas (from 1818 until 1829) and the Magliano area (1842-1843), beginning in the 1840's the entire costal area was also reclaimed, confirming a new interest in valorizing agriculture. Landowners and farmers began their definitive cultivation of the plain, from the hills to the sea, making a first band of vineyards, cereals and pastures, followed by, almost right down to the sea, fertilized areas with intensive farming (vegetables, especially melons, garlic and onions), exported in great quantities by land and sea - and from the 1860's, also by train (Giampaoli, 1988:143-151).



Figure 3: The Avenza and Marinella littoral, detail from the 1777 Panfilio Vinzoni map. (AS Genova, Raccolta dei Tipi, disegni e mappe dell'Archivio di Stato di Genova, 27).

Maria Beatrice's cadastre (AS Massa, Catasto, y. 1821-22 indicates that the costal settlements consisted of only about 15 houses), with six or seven of them located on the eastern littoral (Giampaoli, 1988:169). During the late 1820's and early 1830's, under Francesco IV, the military post and costal defenses were strengthened by the addition of three small forts: Speranza and San Francesco (with the San Giuseppe or Brugiano battery in the middle) on the Massa littoral, Maria Beatrice on the Carrara littoral and supported by the battery at the Avenza landing (Guarducci et al, 2014:105). The forts remained in commission until 1848, then to be abandoned (Giampaoli, 1988:123-126, 140-141). At around 1850, the settlement's buildings had grown to about thirty, including the Ronchi's casino di villeggiatura of Count Paolo Guerra. "At the Bondano, instead, in 1820 Count Piero Ceccopieri had already made his country home." (Giampaoli, 1988:180).

### The Port in the 17th and 18th Centuries

Francesco III d'Este's attempts at reclaiming and colonizing the littoral were crowned half way through the 18th century by his project for a port on the Tyrrhenian. Until then, the most important port was the landing at the Frigido. The river ran close to the town of Massa and its mouth was between Ronchi and the beach to the south of the Carrione. The location was handicapped by almost continuous flooding and the migrating sandbanks at the river mouth, but all the landings between the Parmignola and the Frigid were landings, accessible only to small vessels that had to be hauled ashore for loading and unloading the marble or other merchandise. The long history of the Port of Carrara is already well known with the reconstruction supplied by Bernieri (1983:65-230), even if those pages cause some perplexity regarding the interpretation of

the Milet de Mureau project. Less well known are the reports of engineers and specialists who, since the 18th century, have observed the dynamics of the coastline, the depth of seabed, the patterns of the wind and waves. To better understand the logic of a project that will continue, despite its failures, for two centuries, it is worth remembering that the Duchy d'Este had no access to the Adriatic after the end of the 1500's when the Papal State had taken Ferrara and its territory from the Estense duchy, and that the creation of a port at Avenza or Marina di Carrara, between the Genovese and Lucca republics and the Granducato of Tuscany, would be perfectly placed on well-traveled maritime trade routes and destined to augment the riches of the Duchy.

The Port of Carrara was an expensive and difficult project that was wedded to the just as ambitious Via Vandelli project, undertaken from 1738 to 1751. The new transalpine route connected Modena to Massa, and extending it to the new port would create a corridor linking the Duchy d'Este to the Mediterranean. Both projects had to take into account local morphological characteristics, but while the Via Vandelli, despite the impressive difficulty of the route (the road had to surmount heights in excess of 1600 meters), was inaugurated in 1752, the obstacles of nature that the port had to overcome, well above and beyond design and executive capacities, could not be overcome.

Today we are concerned with the erosion of the low sandy littorals, of ever more consequence as the years go by. These phenomena, at least in Tuscany, began towards the end of the 19th century and the beginning of the 20th and have become more significant because of a whole series of factors that for the most part are anthropic. However, when the idea to build a port on the sandy coast of Avenza was raised in 1750, the situation was precisely the opposite: since the end of the Middle Ages the Tuscan littoral was advancing (the phenomenon was common to most of the Italian peninsula), and recent studies of the Arno, Serchio and Ombrone beaches indicate the decades in the middle of the 18th century as those with the most intense progradation in modern times. It is known that coastline dynamics are conditioned by the sedimentary input of the waterways: between the 17th and 18th centuries the beaches surrounding Bocca d'Ombrone (Guarducci et al, 2011), Bocca d'Arno and the Bocca di Serchio (Piccardi & Pranzini, 2014) have grown at an impressive rate, in exceptional years with as much as 20 meters of annual progradation.

The planned port of Avenza was to be located four kilometers south of the mouth of the Magra and one kilometer from the mouth of the Parmignola while, starting from about a thousand meters south of the landing; we had the mouths of the Carrione, Lavello, Ricortola, Brugiano, Frigido and Magliano (Figure 1). This is a sector of the littoral where, as we will see, the coastline advances at a high rate thanks primarily to the sediments deposited by the Magra, the same sediments that not too many centuries ago buried the Roman port of Luni. This phenomena was known to the designers of the port of Carrara who, when questioning the fishermen of the landing learned that the San Salvatore chapel, built by the edge of the sea forty years before, was now 70 tese (about 136 meters) from the beach (an advancement of about 3.5 meters per year).

The Duchy of Modena could not have been too familiar with littoral management nor with port infrastructures. His bonds to the Kingdom of France brought Francesco III to turn first to Cavalier Sibon (Captain of the French Cavaliers and the Port of Marseilles; Biblioteca Modense, 1782: 67) and then to the engineer Milet de Mureau. De Mureau had studied at the Ecole Polytechnique in Paris and later served as an officer in the French corp of military engineers, where he perfected the method of calculating elevation for artillery and fortification positioning (de Launay, 1933). The state archives of Modena keep a part of Milet de Mureau's signed documents (Cybo Gonzaga, ff. 529-531); these reveal a cultured, up-to-date engineer, familiar with the works of



Sébastien Le Prestre de Vaubam, Henri-Louis Duhamel du Monceau and Roland-Michel Barrin de La Galissonière. He was also well informed of the difficulties encountered during the construction of the ports in Nice, Marseilles and Viareggio. In the *Memoire d'observation sur le Port que S.A.S. monseigneur le Duc de Modena se propose de faire a la plage de Carrare*, the difficulties due to the constant creation of sandbanks off the coastline become immediately apparent, and with honesty and prudence, the report concludes: *si l'on peut surmonter les obstacle et le difficultés que la mer nous opose.*"

Nevertheless, in the fall of 1751 Milet de Mureau began his inspection of the beach at Avenza. Here he finds that the Magra will deposit more sand "*en un jour, que quatre machines a' creuser n'en pouroint enlever dans un an*" and warns that, after a few decades, any jetty built will have to be lengthened. De Mureau also sounded the seafloor for the first 600 meters from the shore; here he discovered a series of constantly shifting sandbanks and shoals that posed a grave danger to any larger vessels that might approach the port. These dangers are also mentioned in a report made by the English engineer William Ockenden a few years later, underlining how the current "creates three or four lines of the aforementioned banks, the last of which is never found less than a mile and a half from shore". The banks are broken by "passages where, when calm, sailors slip through and ever so slowly close the shore".

These dangers are illustrated also in the map of Fig. 4. It displays the littoral between the mouth of the Magra and the Frigido, with the Apuan Alps in the background, around the middle of the 18th century. This map is a plan, never carried out, for the defense of the coast and includes soundings, sandbanks and has added elements in the port area that, just as for the forts, must be considered only as planned. On January 10th, 1752, de Mureau presented his report that, after abandoning the planned river port on the Parmignola and another plan for a jetty (similar to the *fer à cheval* in Civitavecchia), proposes a basin measuring 200 toises de longueur sur 150 de largeur. It was to have a depth of 18 feet, just over six meters, and was to be constructed before building the jetty, as the basin was necessary for loading and unloading the lighters working on the construction of the port and jetties.



Figure 4: A project for the defense of the Apuan littoral with soundings and sandbanks (AS Modena, Fondo Cartografico, Territorio 169).

Excavation work began in the spring of 1752, exploiting a convenient marsh (Acqua Morta, Fig. 5). The excavations were later connected to the sea by canal. To keep the canal free of sediment and marine ingression it was to be equipped with a lock, but the entire sector of the beach with the excavations, from the outset of the project, had to be protected by both a 70 meter long artificial reef, parallel to the coastline and 50 meters out (later to become an integral part of the grand mole, Fig. 6), and by another, 36 meters long, running perpendicular from the beach to shield the landing from the sediments carried in by the northwest currents (Fig. 5). To facilitate the transportation of the construction materials, and once the port was completed, to bring the marble to the ships for export, a three-kilometer long canal was proposed, to be built taking advantage of a sluice in the Carrione. The canal was to connect the basin to the Monteverde road and the nearby rock quarry.

Unfortunately, in the spring of 1753, Milet de Mureau died, but Francesco III (who also lost the support of Louis XV) did not give up and turned to England per advice and funds, bringing the English engineer William Ockenden to Carrara.

In 1749 Ockenden had designed the new port of Ramsgate and in 1756 was responsible for a project for Westminster Bridge (The Beauties of England 1808: 975, Journal of the House of Commons 1755: 214-230). Between 1753 and 1755 Ockenden again investigated “not only above the beach, but once again under water”. He observed that the sediments from the Magra were

distributed along the coast, even beyond the Fosso di Montrone (present day Pietrasanta, about 20 kilometers south of the river mouth) “and they extend away from the beach for more than a mile to sea”. Ockenden criticized de Mureau’s project, the construction of which seemed extremely difficult, slow and very expensive, again because of the strong current, responsible for littoral advancement and the destruction of the temporary breakwaters.

Ockenden’s calculations show that the coastline had advanced by 96 tese (just under four meters per year), but however, when considering the years from 1752 to 1754, he discovered here that the advancement was just less than ten meters per year. This he attributed to the deforestation underway by the populace who were clearing new agricultural areas in the Magra river basin.

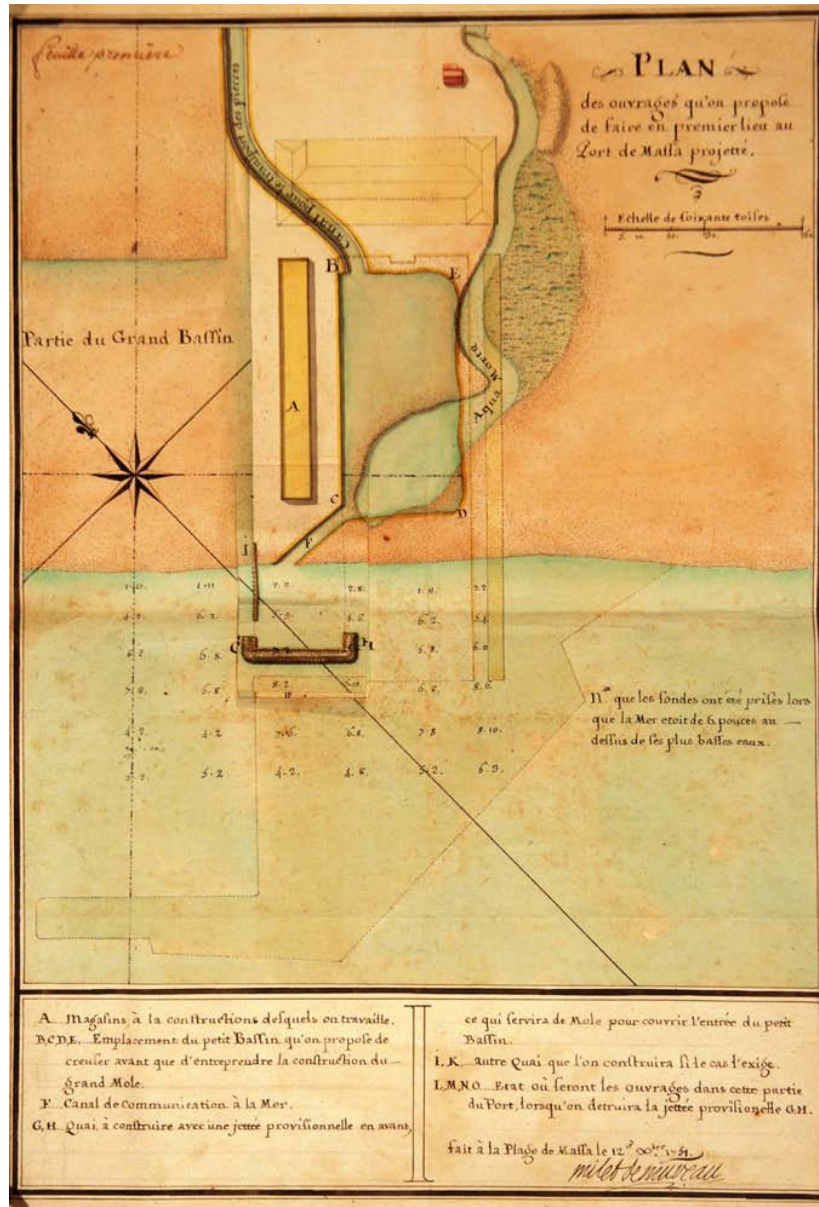


Figure 5: The docks as planned by Milet de Mureau (AS Modena, Carte non inventariata del fondo Manzotti).

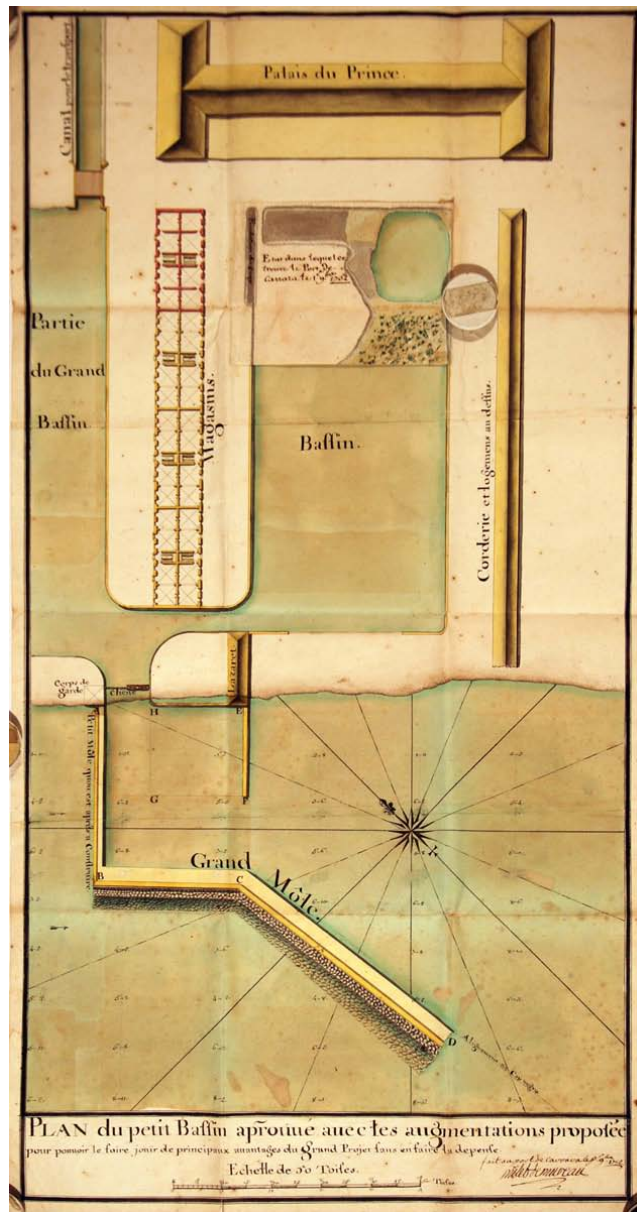


Figure 6: The port as planned by Milet de Mureau (AS Modena, Carte non inventariata del fondo Manzotti).

His project proposed the recovery of the jetty hypothesized by de Mureau and reconfigured the port area, placing defenses and artillery at the head of the breakwaters that surrounded the port. The haven measured 700 feet, with 500 feet taken from the beach (whether referring to French feet, 1' = 0.324 meters, or English feet, 1' = 0.30 meters), is of little consequence. The northwest jetty should have reached a length of 190 meters, the southwest jetty only 80 meters. Apparently the project didn't convince the ever less than convinced Francesco III, who by then was probably sure that any attempt to build the port would be extremely costly and a complete failure.

What we are interested in is that the seabed, half way through the 18th century, was at one hundred twenty tese from shore (about 234 meters, allowing larger vessels to anchor), while in 1821 was now at the level of the beach at Marina di Carrara.

The ample crop of documents still available from these projects, and traces of the incomplete port (the area of the internal basin, the warehouses and the rope making factory mentioned by Lazzaro Spallanzani during his 1783 trip through the Apuan Alps and the Carrara area; cfr Secchiari & Medda, 2001) that are still easily visible on Filippo del Medico's map from the end of the 18th

century (Fig. 7) and in the cadastral map from 1821-22 (Fig. 8), allow us to precisely evaluate northern Apuan littoral advancement between 1750 and 1822, while also being of considerable use in evaluating the following centuries.

While Spallanzani confirms a four-meter per year advancement for the period from 1755 to 1783, it is when we compare the maps made by de Mureau with the cadastral map that we see evidence of the effects of 70 years of progradation. This is a fundamental map for interpreting coastal dynamics in the 17th and 18th centuries, at first dated 1835 and then, because of a typographical error, to 1935 (Bernieri 1983:172). The cadastral map maintains the place names and shows the traces of the port area in the 1750's; they are now at more than 260 meters (confirming four meters per year) from the coastline.

Any further work was brought to a halt, at least temporarily, by the Napoleonic occupation of the Duchy of Modena. It wasn't until 1829 that Francesco IV d'Asburgo d'Este regained control of the Duchy and it was his successor, Francesco V, just before the first half of the 19th century, who reopened the project for the port of Avenza using a model of the port, similar to that of a century before, which still needed a new investigation of the seafloor, as the coastline had continued its advancement.



Figure 7: The position of the port in 1750-55 in the Filippo del Medico map (details); see Figure 2



Figure 8: The position of the port in the Estense cadastral map (details).

Three projects to improve the Avenza landing from the years 1842 to 1845 survived. None of these were completed (work was begun by Sigismondo Ferrari at the beginning of 1845 and interrupted a few months later) although the projects did provoke several other studies and maps (AS Modena, Carte Manzotti). The project dated 1844-45 shows a new jetty, to be built using a new construction technique “invented by the Archduke Massimiliano d’Este”, the son of Maria Beatrice, once head of the Corpo dei Pionieri in Modena, a predecessor of the military engineers, then the superintendent of the Istituto dei Cadetti Matematici Pionieri. Even then the progradation rate at Marina di Carrara was “more than four meters per year, while at San Giuseppe it was only two meters per year and at Viareggio, three.” This data undermines the theory of Dina Albani regarding the thirty-year progradation and erosion cycle that was supposed to affect the Avenza coastline from 1820 to 1910. It is probable that Albani’s theory is based on the report of the commission of the Consiglio Provinciale di Massa presented on February 8th, 1913 (Bernieri, 1983:174) where it is estimated that “from 1821, when the sea lapped the fort,” (but in reality, as shown on the cadastral map, the fort was at least 300 meters from the coastline) “until 1888, the sea had withdrawn at an average of 1.74 meters per year.” This theory was resumed by Toniolo and widened to include the erosion of the northern and southern Tuscan beaches from 1820 until 1850 (Albani et al, 1940: 8, 29, 30).

Returning to the aforementioned projects from the 1840’s, it should be underlined that surprisingly these studies reconsidered the role on littoral advancement of the sediments brought by the Magra. In one of these studies five local ship-owners were asked about the roadstead. They answered that “the Magra is more likely to empty the anchorage than to fill it”, otherwise “the shallow waters that alternate with the sandbanks could not exist”. Without excluding the vast amounts of sediment brought by the Magra, they believed “that these are spread with the rest that the sea sweeps from its bottom and that perhaps constitute the lesser part of the collective tribute of all the Mediterranean’s tributaries.” The orientation of the sandbanks seems to prove that the massive movement of the sands is caused by the strong southeasterly winds that are prevalent along this coast. The consequence of all this was that the new port should once again copy the Civitavecchia model.

In this complex and unsuccessful panorama, the Avenza and Frigido landings, especially after the 1850’s, with the increase in the activity of the marble quarries, were still important centers for exports. The English merchant William Walton, with the financial help of the banker Edward Pate, built a more than 100-meter long loading wharf with two railways connecting the wharf to the shore and cranes. These works stimulated the start of the marble railway in 1873 (the first segment, from the wharf to the Avenza-Carrara line, was inaugurated in 1876) and the birth of the town of Marina di Carrara.

### **The 19th Century: Building the Port**

It wasn’t until 1922 that the first stone was placed for the construction of the northern breakwater. Up to and even after that date port activity took place on three wharves: the Walton, the Binelli (built in 1871, 400 meters to the south of the Walton) and the Pate (about 300 meters long, built at the beginning of the 1900’s north of the Walton, Fig. 9). The first two wharves are shown in the IGM 1:25,000 table from 1878 that covers Ameglia, in the chart by Giovan Battista Magnaghi with soundings taken in 1881 and 1882, and in the 1888 survey of the Avenza landing in the Album dei Porti Marittimi.

When comparing these maps from the late 19th century (Fig. 9, green line) with those of the Ligurian cadastral (1805-1813, Fiumaretta and Marinella, white line) and the 1821 Estense cadastral (Marina di Avenza, yellow line), considerable sedimentary accumulation is visible on the right bank of the last reach of the Magra, causing the narrowing of the river mouth and the advancement of approximately one kilometer of the left lobe.

This phenomenon finds its counterpoint in the erosion of the area extending from the Parmignola to about two kilometers south where the progradation resumes.

Considering the documentation in the previous chapter regarding littoral advancement until 1844, a significant decrease in the rate of progradation on the Avenza beach is recorded between 1850 and 1881. The narrowing of the river mouth and the decrease in coastal advancement is an analogous phenomenon, including the timeframe, to what was happening to the coastline between the Arno and the Serchio. Here the northern beaches of San Rossore continue to advance while the southern beaches above the right hand sector of the Arno are subject to erosion (Pranzini, 1983).

Bernieri seems to affirm that in 1926 the 590-meter long northern breakwater was completed, after which construction began on the extension of the northern breakwater, shown to be over 200 meters long on the 1928 IGM map. At the same time, work was underway on the southern breakwater for a projected length of 500 meters.



Figure 9: The coastline in 1805-1813 (Ligurian cadastral, white line), in 1821 (Estense cadastral, yellow line), in 1878 (IGM 096 3 SO, green line), in 1938 (IGM 096 3 SO, red line), with the location of the 18th century basin (orange, see Fig. 5) and the wharves from the second half of the 19th century.

The international crisis of the years 1929 - 1934 had disastrous effects on the marble trade and delayed the construction and development of the industrial zone behind the port until 1942. However, delaying once again the definitive emergence of the port in the panorama of international commerce, were the years of World War II, when the port was first bombed by the Allies and then almost completely demolished by the retreating German army.

The construction of the port at Marina di Carrara is part of a special moment in the history of this part of the littoral and the differing opinions that have accompanied the various projects are still

echoed in the news today, with opposing factions facing off over the usefulness of the infrastructure and its responsibility for the erosion that is attacking the southern littoral.

The contribution of the sediment brought by the Magra River to the progradation of the coast had already been revealed by the last century's surveys of the port, but it is by the use of geomorphical (Aiello et al. 1976), sedimentological (Cipriani et al., 2001), petrological (Gandolfi & Paganelli 1975) and numerical modeling (Aminti & Cappiotti 2002) studies that we now have scientific confirmation of the acute observations from the 18th century.

It is demonstrable today that the sediments deposited at sea by the Magra River built up the littoral as far as Marina di Pietrasanta, where the sandy deposits from the Bocca d'Arno (Aiello et al. 1976; Pranzini 2004) gradually take on a larger significance. The minor tributaries, both to the north (Parmignola, Carriore, Magliano, Versilia) and to the south (primarily the Serchio), provide a smaller contribution.

The reduction of the sedimentary input from the Magra, caused by the decline of agriculture, the construction of dams and locks and the extraction of inert material from the riverbed, has caused the erosion of the beaches supplied by this river. This process began at the river mouth whose erosion compensated the reduction in sedimentary input allowing the southern beaches to continue to grow.

The area subject to erosion extended ever farther to the south (to the north is the rocky coast of Punta Bianca), decreasing in intensity and modeling the reduction of the prominence of the coastline.

When the port was built, erosion was about to reach the beach at Marina di Carrara and would most certainly have continued to expand, as happens to all littorals when sedimentary input from rivers is drastically reduced. The port's breakwater, intercepting the flow of sediment, caused an inversion in the evolution of the littoral, transforming a beach destined to erode into a beach where progradation has added 300 meters over 70 years. From the end of the 1980's the littoral has ceased to grow (Cipriani et al. 2001). The sediments that have accumulated to the north of the port are missing from the south side of the port, where erosion has been more intense than it would have been without this additional sedimentary deficit. During the construction of the northern breakwater it was already noted that the erosion of the adjacent south beach had caused the separation from the land of the old wharves (AS Massa, Comune di Carrara, series II, envelope 704, 15 March 1923).

Shortly after 1930 it was necessary to build an artificial reef to protect the coastal road, but after damage to it in 1934, work was abandoned (Albani, 1940). As erosion increased to the south, so did the construction of other artificial reefs.

For the first 5.5 kilometers of coast to the south of the port, we have 1.8 kilometers of reef for every kilometer of coastline; seven barriers protect the next 1.6 kilometers of coast.

Responsibility for this erosion is attributed to the construction of the port, primarily by the tourism industry for which the beach is a fundamental resource. This is the aspect over which the clash of opinions between the various stakeholders takes place, even if the evaluations of the scientific community are in agreement in considering the port as exacerbating element in the process of erosion, but not the only cause.



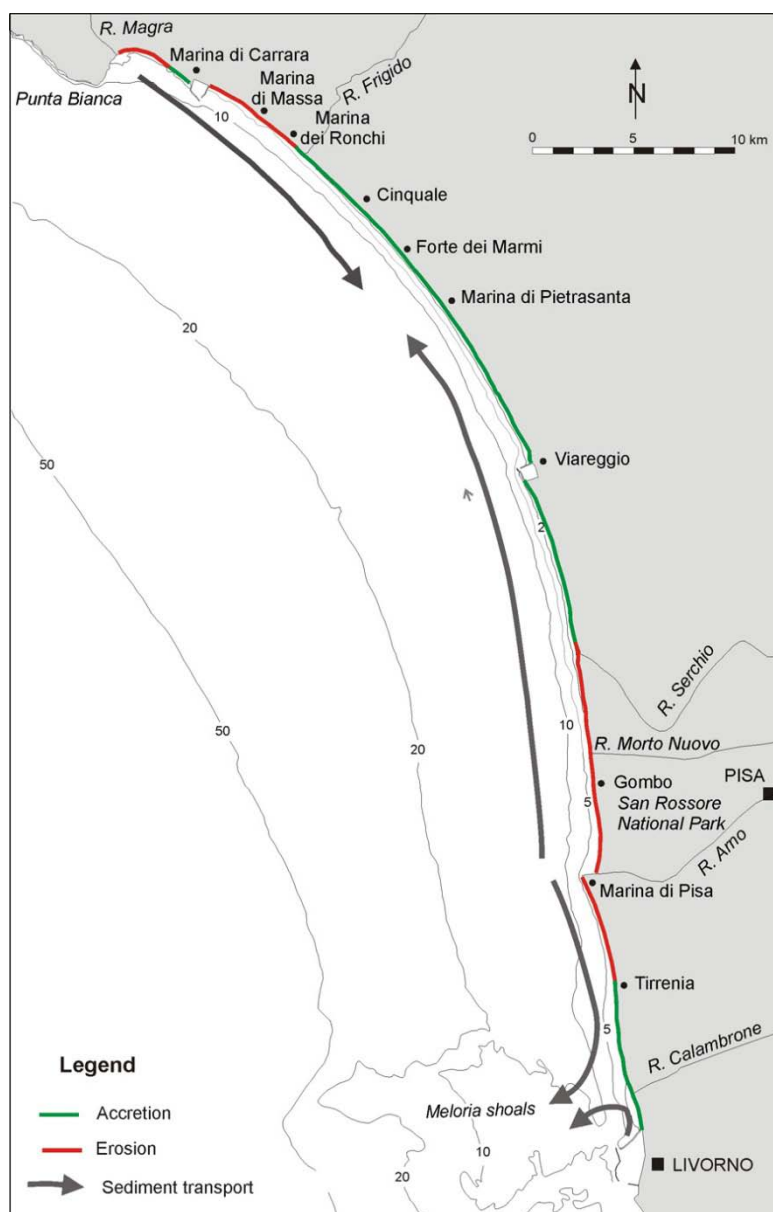


Figure 10: Erosion, accretion sectors and longshore transport directions of the physiographic unit of the study area.

It is here that historic cartography could furnish a useful contribution that has been missing until now. The reason for this is to be found in the scarce temporal resolution of available documents. The only information that can be extrapolated from the cartography and written reports of the period preceding construction of the port is that the rate of progradation on the Marina di Carrara littoral, from approximately three meters per year in the middle of the 19th century, fell to approximately half a meter per year in the years preceding the construction of the port (AS Massa, Comune di Carrara, series II, envelope 704, Schema di relazione sul porto alla Marina di Carrara, 1916).

Confronting the evolution of this littoral with that of analogous segment located laterally to river mouths, we find that erosion would have extended to the entire Marina di Carrara littoral, and later to Marina di Massa, even without the construction of the port. Any cartography or documents that may emerge in future research may perhaps allow us greater precision in evaluating this process, but certainly will not make peace between the two factions that clash over the effects of the port on erosion in the north Tuscan littoral.

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