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A heritage to reveal and protect. Historical water-based paper mills and ironworks in Campania (Italy)

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Abstract

Within the rich heritage of vernacular architectures, hydraulic power works still exists in various parts of the Campania region in the South of Italy: paper mills and ironworks show aspects that require further investigation. Built according to the orographic features of the landscape and in relation to water use and supply, these structures need to be deepened in terms of understanding with respect to their building techniques, production technologies and principal vulnerabilities. Despite its relevance, in fact, the lack of knowledge about this water-related heritage in its material consistency, and the associated risk of loss for misuse or abandonment, needs to be addressed. Accordingly, this paper presents the first outcomes of a study about the evolution of ironworks and paper mills' recurring assets, technologies and building techniques from the proto- to early industrial period; highlighting the historical adaptation skills to water and other local resources, as well as the vital connection of these historical factories to wider hydraulic systems in their territory. It is part of a broader applied research about water-related built heritage carried out at the University of Naples, in which educational activities and exchanges with local authorities have been combined. The paper offers new data on paper mills and ironworks construction history and their sustainable operation starting from the selection of relevant case studies in the regional context and through the crossing of direct field observations and indirect sources (e.g., bibliographical, iconographic, and archival), also to define a knowledge basis for future protection and preservation strategies.

Keywords: *proto-industrial archaeology, vernacular architecture, building techniques, cultural landscapes*

1. Introduction

Among the historical factories typologies working with hydraulic power, paper mills and ironworks represent an interesting yet under-analysed category in built heritage studies. Originally, the building techniques and technologies characterizing such vernacular architecture – together with their location, and their frequent systemic distribution and organization – have been shaped according to the environmental and topographic features of the landscape in relation to water use and supply. Because of its mountainous nature and the numerous valleys and deep ravines crossed by rivers, over the centuries the Campania region in the South of Italy showed a particular aptitude to host such proto-industrial productive systems whose main testimonies are represented by many watermills, tanneries, paper mills, copper, and ironworks, as well as by the structures built to convey and direct the waterways (e.g., aqueducts, drainage systems, canals, and towers). With respect to paper and iron production, this region represents a considerable observatory as it hosts one of the first and most valuable paper mills settlements on a national level (i.e., the Valley of

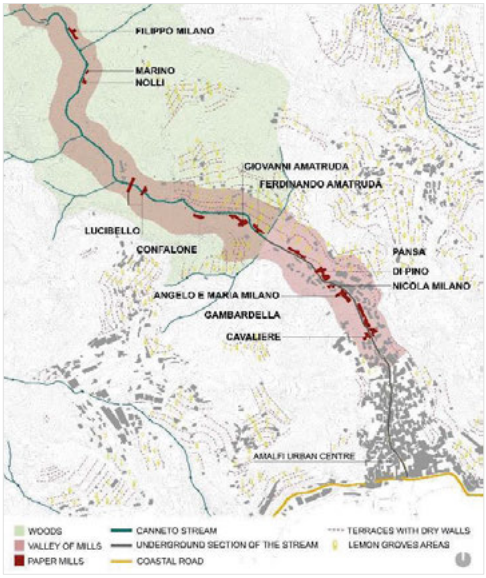

Fig. 1. Amalfi, Valley of Mills. Distribution of the paper mills along the Canneto stream.

Fig. 2. Amalfi, Valley of Mills. The Lucibello paper mill.

Mills in Amalfi), as well as several water-based ironworks (e.g., the Teano settlement), active between the Middle Ages and the second half of the 19th century.

During the last decades many publications have examined various aspects of this heritage, deepening the knowledge also through iconographic, archival, and cartographic tools (Assante, 1977; Assante, 1983; Gentile, 1978; Guida, 1983; Gargano, 1993; Gargano, 1998; Rubino, 2004; Rubino, 2006; Dentoni Litta, 2008). Among these studies, a research and teaching project carried out at the Department of Architecture of the University of Naples Federico II, in agreement with local institutions, wanted to investigate material and intangible components of this heritage by selecting several proto-industrial systems through the five Provinces of Campania. Combining the results of historical research with the field research, the knowledge process allowed us to construct a complex overview about this heritage.

Within this broader applied research framework and in addition to the essays on the Valley of Mills in Gragnano, already published as first results of the research work (Ceniccola, 2017; Russo, Pollone, Ceniccola & Romano, 2018), this essay intends to present some of the results acquired thanks to bibliographic, iconographic, and archival research and field investigations conducted through metric and material-construction surveys. These acquisitions firstly concern recurring assets, material consistencies, technical expediencies and building skills. Secondly, the main vulnerabilities of these vernacular architectures, also in relation to future conservative strategies.

2. Proto-industrial landscape in the Amalfi Coast

Due to the rugged orography and the mountainous nature of its territory, the Amalfi coast has never offered space for extensive cultivation, partially obtained only through the terracing system. For these reasons, over the centuries, alternative activities to agriculture have been launched that promote the affirmation of handcrafted manufacturing – to produce paper, wool, iron, and *pasta* – which, especially between the 16th and 17th centuries, earned these coastal centers fame. Regarding paper production, in 1836 there were still forty-six operational factories in the coastal space connecting Positano and Maiori – eighteen in Maiori, sixteen in Amalfi, seven in Minori, three in Atrani and two in Furore (Camera, 1836; Dal Piaz, 1983; Rubino, 2004; Rubino 2006).
The establishment of such activities in this context was favoured by the rich presence of springs and streams, used both for handicraft processing and semi-mechanized production, as well as by the proximity of landings for the supply of raw materials by sea (Dal Piaz, 1983; Guida, 1983; Gargano, 1998; Rubino, 2004; 2006). For their

strong link with the surrounding landscape, these networks of factories – a first form of "productive" system if considered as a whole – represent the result of the research of solutions for the optimization and sustainable management of natural resources that have resulted in differentiated strategies for adapting to the orography of the sites and the flow of waterways. In the case of localities at the bottom of the valley – such as in Amalfi – simpler water supply systems were defined consisting of small dams and canals that partially diverted the course of the streams to feed the hydraulic mechanisms of the factories arranged in succession. Otherwise, in correspondence with particularly steep and uneven terrain or more irregular and weaker streams – as in the Furore fjord – the conveyance of water took place through a more complex hydraulic system consisting of a dense network of masonry structures such as canals, aqueducts, dams, sluices, and basins – also used as reserves during periods of drought. The water diverted from the main course and conveyed through these hydraulic infrastructures then directed into the factories through the piezometric towers – cylindrical in shape, enlarged at the base to better resist the pressure of the water (Perriello Zampelli, 1959; Guida, 1983).

Interesting examples of these "adaptations" of the landscape remain in Amalfi but also in other coastal contexts. In Positano, for example, there are traces of a complex system of factories arranged in series and fed by a network of canals supported by mighty buttressed walls, tanks, and sluices (Guida 1983). Furthermore, in the fjord of Furore there is an example of a factory in which a mill and a paper mill coexist, developing vertically the chain connection also present elsewhere (Rubino 2004; 2006).

2.1. The Valley of Mills in Amalfi: a system of vernacular architecture and nature

The Valley of Mills in Amalfi is the site which best represents the peculiarities of this proto-industrial landscape: here the natural components and those resulting from the changes made by man coexist in a fascinating balance. Starting from the 18th century, the Amalfi valley became the subject of travel literature and iconographic testimonies by Italian and European artists and *voyageurs* thanks to those choral values that remain still unchanged, despite the abandonment and the changes occurred over time. Values that are attributable to the coexistence in the same landscape of the paper mill system – often associated with mills – of the network of routes that connect them, of the hydraulic infrastructures and of the canals for irrigation of the surrounding fields deriving from them.

Extending outside the northern gate of the city (*Porta Hospitalis*), the narrow valley is softened along the slopes by terraces used for different crops and crossed by the Canneto stream (or, more anciently, Chiarito) which originates from the Lattari mountains in the territory of the nearby municipality of Scala. This watercourse is called *Chiarito di Sopra*, for the stretch in which it flows in the open to the Ferdinando Amatruda paper mill, and *Chiarito di Basso*, for the one that descends from this structure to the sea, conveyed below the road completed in 1939 (Rubino, 2006). Thirteen paper mills are preserved along the watercourse (Fig. 1), which receive state protection except for the Gambardella paper mill. They are for the most part privately owned and, over time, have been transformed into homes or abandoned, except for the Nicola Milano paper mill, hosting the *Museo della Carta*, and the Ferdinando Amatruda one, still used for the same productive activity.

As regards the construction and evolution of these factories, it is believed possible that some of them derived from the conversion of mills, or more probably, of fulling mills to produce wool, built in correspondence with the *Chiarito di Basso* between the 12th and 13th centuries, so much so that they originally acquired the name of "paper fulling mills". As a result of this transformation process, the new paper mills would have preserved the spatial organization of the pre-existing settlements, inheriting some of the "technologies" and machines already in use (Gentile, 1978; Rubino, 2006). Other structures built further

upstream along the river were added to the factories of the first nucleus located close to the urban centre. There were eleven units, as shown in the *Catasto Onciario,* that dates to 1741-1742. The end of the 18th century into the early decades of the 19th saw the transition from an artisanal process to one semi-mechanized. This led to a further expansion of the production area towards the upper part of the valley, along the more rugged slopes, where the beating force of the water was greater. In this way a total of sixteen factories were reached, as noted in 1836 (Camera, 1836; Dal Piaz, 1983; Rubino, 2004; 2006).

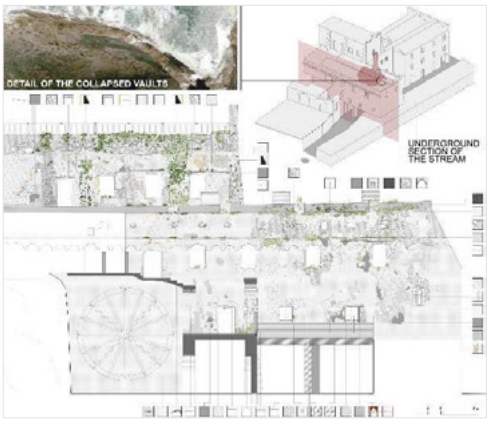

Fig. 3. Amalfi, Valley of Mills. Northern elevation and details of the Di Pino paper mill (Source: Malangone, Xiques Arteaga 2011).

Fig. 4. Amalfi, Valley of Mills. Processing machinery and rooms of the Di Pino paper mill (iron wheel*; fuso, pila, tino, torchio* or *strettoja,* and *spanditoio*).

In addition to the wise use of water resources, the sustainability of this proto-industrial system – as clearly emerges from the direct reading of materials and construction types – had to be sought in the ability both to adapt the architecture to the orography of the sites and to make the best use of the raw materials available in those places for the construction of the factories. Regarding the first point, field investigations have shown that the oldest paper mills have small volumes and irregular layouts, adapted to the conformation of the spaces. In fact, different architectural solutions can be found in relation to several factors and, firstly, to the orographic conditions of the sites – e.g., foundations dug into the rocky bank, structures partially leaning against the rocky walls. Secondly, with respect to the distance from the watercourse or the most favourable climatic conditions – e.g., different distribution and shape of the openings in the elevations. Furthermore, despite the manufacturing destination of these factories, an adherence to the vernacular construction tradition of rural buildings of the Amalfi coast has emerged (Pane, 1936; Fiengo & Abbate, 2001). Clearly referring to the small structures used as warehouses and service rooms (*monazeni*) still existing in the fjords of Furore and Crapolla (Vitagliano, 2014) and, in some ways, to the mills of Gragnano, very similar to the latter, some of the Amalfi factories – in particular, the Cavaliere and Nicola Milano paper mills – are characterized by the recurrence of small rooms and pseudo-rectangular layouts with vaulted roofs. In these cases, also due to the limited space for processing, the rooms for drying the paper sheets (*spanditoi*) were built near the main buildings in such positions as to exploit more favourable ventilation conditions.

Elsewhere, and especially in correspondence with the *Chiarito di Sopra*, the paper mills demonstrate greater autonomy from the traditional typologies of the coastal rural heritage, adhering to a more "functionalist" architectural model. Structurally more impressive than the others, these paper mills are characterized by a stronger synergy between form and function: the definition of more regular buildings is preferred, also placing them straddling the stream to optimize the exploitation of hydraulic power – as in the Lucibello factory (Fig. 2) –, and

of such dimensions as to allow the installation of machinery suitable for chain production cycles (Guida 1983). Arranged on several levels, these structures are defined by masonry vaults and wooden slabs, as well as completed, on the top floor, by the *spanditoi* closed with double-pitched wooden roofs. Examples of this type are still recognizable in the Pansa, and Ferdinando Amatruda paper mills and, despite the ruderal state, in the Confalone, Lucibello, Marino, Nolli, and Milano ones.

Regarding the characterization of building materials found, there is a widespread use of those available on site such as first limestone – widely used for the construction of both ashlars and mortars or plasters – yellow tuff and, more rarely, grey tuff. The absence of plaster and the ruderal condition of these structures have facilitated the direct reading and stratigraphic interpretation of the constructive elements. We highlighted a recurrence of irregular masonries, in which building materials, primarily limestone, are used in ashlars and flakes bound with mortars made by lime and *pozzolana*. Rarer is the presence of masonry with consecutive construction sections (*a cantieri*) which are, however, found above all in the factories built further upstream.

The vaults, used both for intermediate floors and roofs, are structurally defined by limestone ashlars, sometimes mixed with elements in yellow tuff, or exclusively made up of blocks of the latter material. In addition, there are vaults consisting of concrete with limestone and tuff aggregates of various sizes (*volte 'a getto'*), as can be seen in the section of the collapsed vaults in the Di Pino paper mill (Fig. 3). The reading of extrados reports the presence of impermeable layers in "beaten lapillus", consisting of a mixture of *lapilli*, lime and *pozzolana* (Fravolini, Giannattasio & Rotolo, 2008; Ceniccola, 2014). Due to the availability of wood from the woods of the Amalfi Republic and the chestnut groves of Scala and Tramonti, the factories of this valley, more than in any other in this coast, have a notable occurrence of intermediate wooden slabs and double pitched roofs with wooden beams or trusses, mainly within the rooms intended for drying the paper sheets.

Despite the transformations over time and the current state of abandonment of most of the Amalfi paper mills, the system of sluices, basins and supply canals that fed the factories connecting them in series is still recognizable. The identification of spatial articulation of such buildings and of their "technological" equipment – aspects carefully investigated by this study –, has testified a strong "functional" link to the paper processing phases (Fig. 4). In most cases the main phases of this artisanal work took place at the lower levels, more easily served by water canals or piezometric towers. Here, the wooden crates for the collection of the raw materials (i.e., cotton, linen, or hemp rags) are kept together with the stone tanks (*pile*) where the latter were deposited after the maceration phase (*marcitura*), to then be crushed and reduced to mush with the addition of water by means of wooden hammers nailed at the ends. Still found in most of the paper mills, the multiple hammers were operated by a transmission shaft (*fuso*) connected to the hydraulic wooden (or iron) wheel powered by the driving force of water. During the 17th century, in some of the factories this shredding system was flanked or replaced by the more efficient Dutch refining cylinder, made of wood, iron or stone. All variants are still preserved, for example, in the Lucibello paper mill. Another essential element of the manufacturing process consisted of a circular masonry tank (*tino*), in some cases covered with precious ceramic tiles, in which the mush was deposited and, mixed with glue, collected in a rectangular frame (*cassio*) that defined the final shape of the product. The sheets thus obtained, alternating with wool felts, were pressed inside a wooden press (*strettoja*) to let the water out, laid out to dry and, finally, smoothed (Gargano 1993; 1998).

3. Architectures for iron production. Metallurgic complexes in the regional context

Among the proto-industrial assets investigated, the research also focused attention on ironworks by analysing, even in these cases, the results of the skills relating to the exploitation of natural resources in constructive terms. As for paper mills, the proximity of waterways for generating the hydraulic

energy to operate bellows and hammers, determined the choice of the sites for building; this was combined with the need of large forests, especially chestnut groves, for the (less sustainable) production of charcoal used to power the furnaces, for which, moreover, the action of air was also essential. In addition to these factors emerged another substantial condition linked to the possibility of extracting raw materials on site or in mineral deposits close to the factories which, however, were never conspicuous in the regional context, considering the massive imports from the Elba Island.

The metallurgical settlements had a certain diffusion in Campania already in the Angevin age, to reach a larger number in the following centuries, especially starting from the mid-16th century. This increase was partly attributed to the southward migration of entrepreneurs and skilled workers from Liguria, where the metallurgical proto-industry had been active since the 13th century – in fact, we speak of "Genoese" or "Catalan" ironworks that used the low heat (Rubino, 2009; Rauccio, 2010). At the beginning of the 19th century, the Campania production plants, whose management had passed several times from the public to private, were still in operation at the sites of Pianodardine, Atripalda, Serino, Giffoni, Acerno, Amalfi and Sant'Agata dei Goti (in the ancient provinces of Principato Citra and Ultra) and in Maddaloni and Teano (in that of Terra di Lavoro) (Barra, 2000; Rubino, 2004).

Among the oldest settlements considered there is the Amalfi ironworks, known as early as 1361 and active until 1815 (Assante, 1983; Gargano, 1993; Rubino, 2004; Rubino, 2006). Built in the most upstream part of the Valley of Mills where the Ceraso and Gorgone springs are grafted into the Canneto stream, what remains of the structure still testifies the ingenuity of the system built to generate the hydraulic energy.
Partly straddling the stream, the ironworks consisted of two buildings, of which the smaller featured the same system of the largest on a smaller scale. The latter was equipped with three hollow wooden pipes (*trombe idro-eoliche*) – made of masonry or iron in other contexts – into which the water deriving from the aqueduct was canalised.

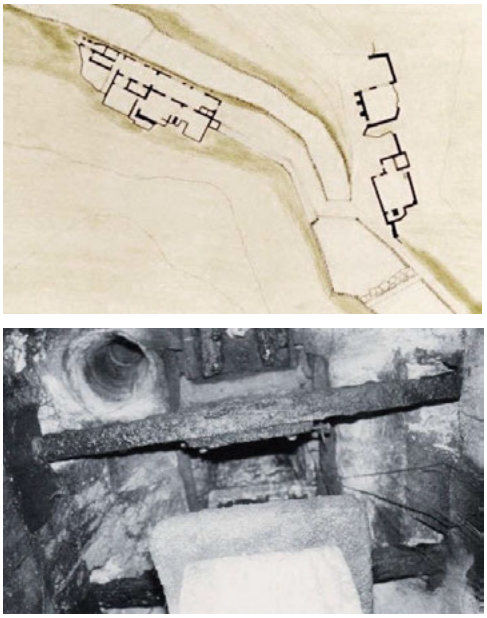

Fig. 5 and Fig. 6. Teano, the Salvi metallurgic complex along the Savone River: the ironworks (on the left) and the copper factory. Below: Salvi ironworks. The hydro-aeolian pipelines (Source: Rauccio, 2010).

This last, still partially preserved, was supported by a system of arches in pseudo-regular masonry made of limestone ashlars and flakes. The current of air generated by the fall of water inside the pipes – adjustable by means of a valve – fed the fire of the furnace for melting the mineral; the water subsequently flowed into a masonry basin (*bottazzo*) from which, through an inclined conduit, it operated by fall the wheel whose axis generated the movement of the hammer for beating the iron.

Iron manufacturing also flourished in Teano, currently the province of Caserta, from the beginning of the 14th century to the 16th and 17th century. A complex consisting of an ironworks and a copper factory in the *Gomite* locality is currently preserved here. Its construction (1830-1845) was due to Nicola and Bartolommeo Salvi, descendants of a family of metallurgic entrepreneurs coming from Liguria who settled in Campania during the second half of the 16th century and whose ancestors had also dealt with the Amalfi ironworks since the end of the 17th

century (Salvi, 1991; Rubino, 2009; Rauccio, 2010). Further refining the techniques of adaptation to the features of that territory, the nineteenth-century builders were able to derive the greatest benefit from the available resources (e.g., the rich chestnut groves of Roccamonfina and the waters of the Savone River), defining structures perfectly suited to the morphology of the landscape and a complex hydraulic system capable of feeding both the factories. Derived from the main course of the river by means of a dam, the water was collected in a loading basin, and, through canals, it activated the wheels of the hammers; passing into a smaller tank it fed two mills to then split and fall partly into the river and partly into the hydro-aeolian pipelines (*trombe idro-eoliche*).

The two factories were built in such a way as to accommodate the contour lines as much as possible, which, in fact, defined their position (Fig. 5). The body of the ironworks – the best preserved of the two – develops parallel to the river, following its course also in correspondence with the waterfall, overcoming a difference in height of about 20 m through a system of rooms and stairs, partly excavated in the rock. As emerges from the analysis of the masonries, the construction techniques used here show a remarkable ability in working with grey tuff, a raw material certainly more available in the province of Terra di Lavoro. This material is used in well-squared blocks of considerable size bonded with thin lime-based mortar joints for the definition of extremely regular masonry. The same regularity characterizes arches and vaults, consisting of ashlars of the same material, as can be seen in the well-preserved barrel vault of the coal deposit. The other slabs, as well as the single or double pitched roofs with beams or trusses, are made of chestnut wood, also available on that site, which, when transformed into coal, was also used to power the furnaces.

The iron processing took place, therefore, by exploiting both hydraulic and wind energy in a very ingenious way: the flow of water – regulated by a sluice – through a vaulted canalization, also made of blocks of grey tuff, reached three wooden cogwheel that operated the hammers for beating the raw material and the slag. Therefore, the water was canalised partly towards the drainage mouths, from which it returned to the river, and partly towards the *wind chambers* which are large vertical ducts in grey tuff masonry extended for the entire height of the difference in level of the waterfall. Here the water flow gained speed due to the vertical fall and beating on the surface of slightly convex stones generated a vortex of air (Fig. 6). The latter, canalised into another pipeline, fed the melting furnace and the four heating fires of the ironworks before being conveyed to the copper factory.

4. Conclusions

What is presented here represents the first result of a research which has the main objective of building an in-depth knowledge of this proto-industrial heritage through the reading of its components at different scales. It should also help to define adequate conservation and enhancement strategies. In this perspective, the first assumption was to consider these architectures not in isolation but as elements of a landscape system in which natural resources, hydraulic infrastructures and buildings have the same importance and are a synthesis of relevant material and intangible values. Downstream of a phase of systematization of previous knowledge, the research was able to count on a meticulous field reconnaissance conducted through the dimensional and material-constructive survey, carried out mainly with traditional techniques. This has made three things possible. Firstly, to verify or reveal the material traces resulting from the adaptation of the landscape to better exploit natural resources. Secondly, to verify the consistency of the production facilities still preserved, with particular attention to the recognition of technical and technological solutions resulting from the application of practices related to local vernacular knowledge and the use of raw materials available on site. Finally, to assess the state of conservation and the main vulnerabilities that characterize these assets, also in relation to the risks accelerated by abandonment and the condition of ruin, as well as the possibility of better grading

the conservation guidelines. This interpretative process is therefore an indispensable step also in relation to the opportunity to improve knowledge and promote the recognition of all the traces of which these vernacular production systems are composed, both at the scale of the landscape and at that of the individual technical-constructive choices. A knowledge acquisition, finally, that is useful to adequately weigh the conservative choices both with respect to the possible expansion of the physical and perceptive use of these places, and to the provision of conservation and protection actions that will need to be calibrated so as not to distort the delicate balance existing between the built and natural components of these cultural landscapes.

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